NISTIR 4546

# Intelligent Building Technology in Japan

**Arthur Rubin**

U.S. DEPARTMENT OF COMMERCE
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and Technology
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Gaithersburg, MD 20899

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ELECTRIC POWER RESEARCH INSTITUTE
Commercial Building Systems

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**Abstract**

In May 1990, the author of this report visited Japan at the request of the Department of Commerce's Japan Technology Program, to assess Japanese experiences with 'intelligent building' design, construction and use. The state-of-the-art was determined by visiting advanced buildings, building complexes, and interviewing architects, engineers, and researchers and academics. Discussions also were conducted with organizations engaged in promoting the use and design of intelligent buildings.

In general, Japanese experiences have paralleled those in the United States. In both countries, advanced building technologies have been employed to advance organizational effectiveness and personal productivity. A major problem shared by the two countries has been the lack of standardization of hardware and software (protocols), resulting in major difficulties in integrating equipment from different manufacturers, and in some instances, diverse products from the same manufacturer. Intelligent building design in Japan differs from that in the United States in several ways. They incorporate new systems and products into their buildings as soon as they become available. They stress the need for a high quality environment - amenity - more than the United States. The commitment for developing improved intelligent buildings includes active governmental involvement by two major ministries and other institutions such as banks.

**Keywords:**

Building systems, building technology, intelligent buildings, Japanese buildings, office automation

## Executive Summary

In May 1990, the author of this report visited Japan at the request of the Department of Commerce's Japan Technology Program, to assess Japanese experiences with 'intelligent building' design, construction and use. The state-of-the-art was determined by visiting advanced buildings, building complexes, and interviewing architects, engineers, and researchers and academics. Discussions also were conducted with organizations engaged in promoting the use and design of intelligent buildings.

In general, the Japanese experiences have paralleled those in the United States. In both countries, advanced building technologies have been employed to advance organizational effectiveness and personal productivity. A major problem shared by the two countries has been the lack of standardization of hardware and software (protocols), resulting in major difficulties in integrating equipment from different manufacturers, and in some instances, diverse products from the same manufacturer. Intelligent building design in Japan differs from that in the United States in several ways. They incorporate new systems and products into their buildings as soon as they become available. They also stress the need for a high quality environment - amenities - more than the United States. The commitment for developing improved intelligent buildings includes active governmental involvement by two major ministries and other institutions such as banks.

Among the 'leading edge' technologies seen in Japanese buildings which merit description are:

1. Intelligent cards used extensively for security, reserving conference rooms, credit transactions, telephone usage and purchases.

2. Earthquake and sway monitoring systems measure building movement and provide information to computers which control roof ice storage systems to counteract building sway.

3. Crystallized liquid ice thermal storage systems combined with natural circulation of the refrigerant, using off-peak power, are used for climate control.

4. Infra-red sensors are used at workstations to regulate HVAC, lighting and venetian blind movement.

5. Fiber optic systems transmit sunlight to offices and other interior building areas.

6. Teleconference rooms with full capabilities to electronically transmit and receive all types of information in real time - this includes video, data, voice.

7. Robots are used for interoffice document transfer, mail delivery, and facility management activities such as cleaning and inspecting for structural damage.

8. Advanced centralized monitoring and control systems are employed for energy conservation, safety, security, and building management.

9. Fragrances are introduced into offices as amenities.

10. Electromagnetic interference protection systems shelter a building from outside electromagnetic noise, enabling information transmission without cabling.

11. Sunlight and electric light control devices are regulated automatically by a system which alters window blind configurations in conjunction with controlling electric lighting.

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Finally, and above all, I want to acknowledge my debt to the many Japanese organizations, and individuals too numerous to name, for their help in this endeavor. Without their cooperation, willingness to share information, and generosity with their time, it would have been impossible to conduct this study.

## 1. Introduction

While the concept of 'intelligent buildings' was initiated in the United States, in recent years the Japanese have been at the forefront in rapidly applying new technologies in building designs and applications.

The major impetus for using intelligent buildings in Japan and in the United States, is the desire to increase white collar productivity and organizational effectiveness. Similarly, in both countries many sectors of the societies contribute to the design and use of advanced technologies in offices. Architects, construction management firms, end-using organizations, manufacturers of building products and systems, computer and telecommunications vendors and countless others have a "stake" in intelligent buildings. Unlike the United States however, two government ministries [The Ministry of Construction (MOC) and the Ministry of International Trade and Industry (MITI)] are actively promoting this concept and supporting activities to enhance its development (1). These ministries are convinced of the need for government support to foster the design and use of offices that take full advantage of new technologies in enhancing office productivity while simultaneously improving working conditions for office workers.

In order to learn more about Japanese experiences with intelligent buildings, a visit to Japan was arranged by the Japan Technology Program, Department of Commerce. This report summarizes the information obtained during this visit. The trip was sponsored to assess the recent advances in Japanese intelligent buildings, and the implication of its effects on the United States construction industries.

The state-of-the-art in intelligent building design and use was determined by visiting advanced buildings and building complexes, and interviewing architects, engineers, and researchers and academics. Discussions also were conducted with organizations engaged in promoting the use and design of intelligent buildings. (A list of organizations visited appears in Appendix 2.) The topics of discussion ranged from the changing characteristics of building users, to experiences with new technologies, to forecasts of intelligent building design.

Since 1982 the National Institute of Standards and Technology (NIST) has been performing research to determine how office automation affects the working environment for federal employees, and consequently, their ability to effectively perform their jobs. These studies have culminated in a series of reports. (2-6) In addition, NIST has been actively involved in international studies and conferences dealing with intelligent buildings. NIST also participated in a National Academy of Science (NAS) study of "Electronically Enhanced Office Buildings" (7) and conducted a survey of corporate architects and facility managers in conjunction with the American Institute of Architecture (AIA) (8). Thus, the perspective brought to the trip covered experiences in the federal and private sectors dealing with the impact of new technologies on office design and "white collar worker" productivity.

### 1.1 Study limitations

During the two week investigation, the author visited more than 20 organizations and conducted interviews with more than 50 people in Japan. Many discussions took place during visits and tours of new buildings. Consequently, the report summarizes the author's general impressions of the buildings, the technologies employed, and the highlights of discussions about intelligent building experiences and forecasts by Japanese experts. Specific buildings were not evaluated; there was insufficient time for such an examination. However, some buildings and technologies are described in as much detail as possible, given the constraints of time and the availability of English language material.

## 2. Background

### 2.1 Intelligent buildings - Definitions

While the term 'intelligent buildings' has been used for almost a decade, it has been subject to many different interpretations. The most common definition of an intelligent building stresses the use of advanced technological systems and components, which are linked and controlled by computers and advanced telecommunications techniques, to perform operational and building management functions.

Recently, the emphasis on technology as the distinguishing feature of intelligent buildings has been expanded to other issues. Both a National Academy of Science study and Japanese firms emphasize the importance of buildings being responsive to the needs of end-users (7). These requirements are not restricted to functional ones but include features to enrich and improve the total office environment. This viewpoint states that value is added to a building by providing intelligence and enhanced quality. In Japan, building characteristics designed to improve the quality of work life are designated as 'amenities' - a term in widespread use, and considered an essential design quality.

Figure 1 illustrates the Takenaka Komuten Corporation's description of the features of an intelligent building. While the breakout of functions is unique to this corporation, the characteristics described are typical.

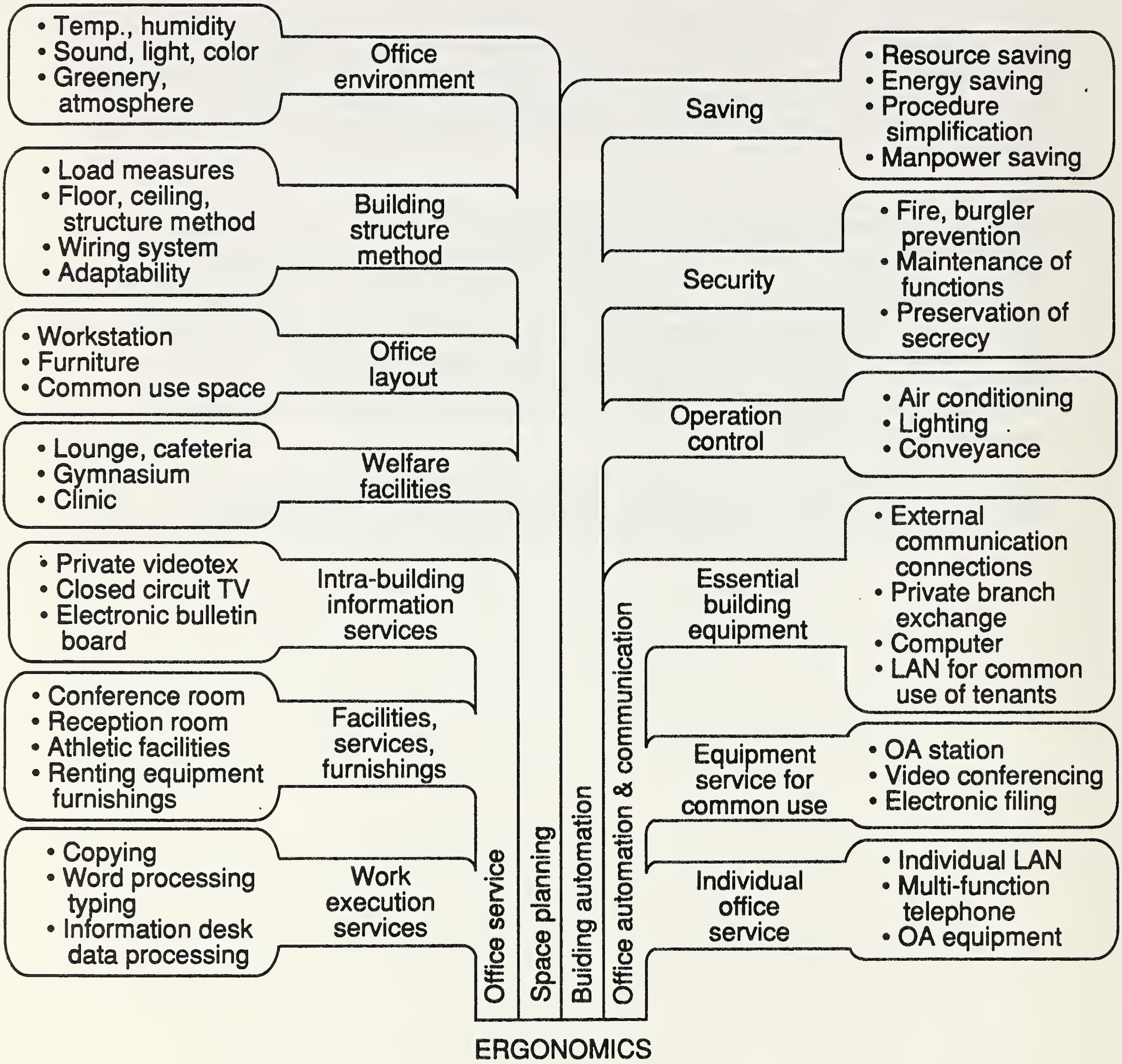



Figure 1. Intelligent Office System Research
(Source: Takenaka Komuten Corporation)

## 2.2 Evolution of intelligent buildings

The evolution of intelligent building designs and the resulting experiences in the two countries display differences and similarities.

In the United States, vendors of hardware products and those promoting Shared Tenant Services (STS) have provided the major impetus for the concept. In Japan, MITI, MOC, NTT as well as major design and construction firms decided that a strategic goal was to position Japan at the forefront of intelligent building technology (1). This goal has been expressed in terms of meeting three objectives:

1. Increase the efficiency of business
2. Adapt to the new information society
3. Adapt to socio-economic changes

Associated with this broad definition is the comprehensiveness of their approach. The nature of the technology used in intelligent buildings is said to follow the rules of economies of scale. The concept therefore is moving from a single building to a building complex, and finally to a city and beyond, e.g. to multi-national corporations.

## 2.3 Building research

The Japanese have an abundance of research laboratories to support their intelligent building program. Each of five major Japanese construction management firms (among the eight largest such firms in the world - see below) have research facilities, programs, and budgets, approximating or surpassing those of the Building and Fire Research Laboratory (BFRL) at NIST - the only similar organization in the United States. These private building research laboratories exist in addition to the Building Research Institute of Japan, a national laboratory with a mission similar to BFRL, but somewhat smaller in size. The private sector in the United States has no comparable research capability to its Japanese counterparts.

**Table 1. Top Contractors Internationally (10)**
**(Ranked for Total 1989 Contracts)**

| Rank | Firm | $ Million (Total) |
|---|---|---|
| 1 | Fluor Daniel (U.S.) | 16,447 |
| 2. | Shimizu (Japan) | 13,152 |
| 3. | Bechtel (U.S.) | 12,010 |
| 4. | Kajima (Japan) | 11,940 |
| 5. | Taisei (Japan) | 11,502 |
| 6. | Takenaka (Japan) | 11,254 |
| 7. | Brown and Root (U.S.) | 10,977 |
| 8. | Obayashi (Japan) | 9;972 |

Typical research includes such basic topics as structures, materials, indoor environment, robotics, artificial intelligence, energy conservation, disaster prevention and earthquake engineering in addition to activities dealing with

building types ranging from nuclear facilities to housing. The scale of intelligent building research ranges from examining requirements for offices and buildings to those for urban complexes and cities.

Augmenting these research activities are those performed by organizations promoting intelligent buildings and new offices, which are described in Chapter 8.

**2.4 Intelligent buildings in Japan and the United States**

A significant factor affecting intelligent building construction in Japan is a shortage of office space. The Japanese Ministry of Construction estimates that for 1989, the demand for intelligent building construction was 50 million square meters, and 20 million square meters for renewal or remodeling (1). The estimate for the intelligent office market in the future is indicated in table 2 (11).

**Table 2. Intelligent Office Market in Japan 1987-1996 (Billions of dollars)**

| | |
|---|---|
| Construction | 93-100 |
| System Equipment | 7-14 |
| Building Services & Communication | 93-129 |
| Total | 193-243 |

This "boom" in office building offers an excellent opportunity to apply high technology concepts to building construction, while improving the working environment. The Japanese envision high technology buildings to solve space problems, while improving the quality of life.

"As has been typical in seeking solutions to internal problems, the Japanese have attacked the construction of office buildings from a new perspective. They view the building as a system and seek systems solutions. This allows them to not only address the domestic problem of improving working conditions, but to develop new technologies that can be marketed abroad. The concept of the intelligent building is key to this strategy. It is approached as a system which can be developed to be marketed as a unit, such as a refinery support system or a mass transport control system. Various products to implement this concept will become "spin-offs generating new markets" (12).

Incentives are available for developers of intelligent buildings. For example, a substantial tax break is given to those who design and construct intelligent buildings. Furthermore, financing also is subsidized. For example, the cost of money for intelligent buildings can be as low as 2-3% compared to the 10-14% paid by United States firms. In the United States, design is separated from finance; in Japan, they are part of a large comprehensive package which is centrally planned and fostered. Commissioning and maintenance operations also are separate in the United States but not in Japan (13).

Economic and cultural factors also must be considered when comparing Japanese experiences with intelligent buildings with those in the United

States. For example, the occupancy rate of offices in the two countries differ considerably. In Tokyo and Osaka there is virtually no unoccupied office space (vacancy rates .02% and .04%). In contrast, the latest findings in the United States, show that the average vacancy rate for the United States as a whole is 19%, for Manhattan 14%+ and for Los Angeles 17%+ (14). The construction of intelligent buildings in Japan is therefore a relatively risk-free enterprise.

A critical difference between the Japanese and United States building construction industries is the cost of land. Land in downtown Tokyo is more than five times that of mid-town Manhattan. As a result, the relative costs of planning, amenities, technology and the building are a small fraction of the total cost in Japan. The cost-effectiveness of design decisions therefore are subjected to a different kind of analysis than comparable ones in the United States. Another factor which contributes to different design decisions on outcomes in the two countries is the emphasis in Japan on long-term (life cycle) costs as opposed to initial expenditures. This is true even for many speculative office buildings.

In order to understand the Japanese intelligent office today, it is important to realize that the design of traditional offices in Japan differ from their counterparts in the United States. For example, in most Japanese offices desks are arranged in a "face to face" configuration. A supervisor is located at the "head" of a series of desks facing one another, occupied by those under his supervision. The "open office" in Japan is a wide expanse of such groupings of desks, without dividers. Private offices are a rarity, and are occupied only by top management personnel. In contrast, open offices in the United States typically have systems furniture, with dividers of various heights providing a measure of visual and auditory privacy to workers. Also, the United States has a long tradition of providing private offices for management and professional employees. In recent years, such private offices are becoming rarer in many buildings, except for executives.

One of the reasons for the contrasting approaches in performing office work is rooted in cultural differences. In the United States, the "knowledge worker" values his or her independence. This is translated into the desire to have personal data bases, some influence in how work is performed, as well as control of environmental features such as lighting and HVAC systems. Joint activities are performed by combining information held by the individual, with that of colleagues, when such cooperation is required. In contrast, the Japanese worker greatly values "team membership", which extends to the working group and the organization as a whole. Advancement for the individual often is achieved by subordinating personal goals to those of the group. Automated systems and organizational cultures in the two countries are partially a reflection of these diverse viewpoints.

However, a convergence of these differences is becoming apparent. In the United States, there is an increasing emphasis on the need to operate effectively as a member of a group, while in Japan, more and more young people are demanding that their individual needs be recognized and fostered. Study findings in both countries support this view. Similarly, the office worker's needs and desires in Japan are rapidly changing, becoming more like those of his or her counterpart in the United States and Europe. The Japanese design, construction, and organizational communities are responding to these changes.

## 3. General observations

The author visited several intelligent buildings and building complexes, e.g. business, commercial and multi-use "parks". A significant feature of the buildings was that their sole, or major tenant, was typically an organization with multi-national interests and/or holdings. Building designs and their technologies reflect this broad and "external" perspective in several ways, some based on amenities, others on technology.

Considerable attention was given to the buildings' exteriors and internal public spaces. Consistent with Japanese traditions, there was a conscious intent to blur the boundary between buildings' interior and exterior spaces, treating them as integrated elements of a total design. This was as true for individual buildings as well as building complexes where walkways were used to link separate structures. The public spaces within and outside the buildings were designed to encourage people to linger, have informal conversations, and enjoy scenic features such as plants and trees.

A major feature of the buildings examined was the presence of advanced information and telecommunication systems to conduct business and perform building management functions. Examples of these systems are: closed circuit television in conference rooms, centrally controlled energy management and security, and access systems based on "smart cards". An important feature of these systems is their capability to communicate effectively with the "outside world". That is, they are designed to exchange information in any form, electronically, with other organizations throughout the world. For example, multi-national organizations such as Toshiba and Fujitsu facilitate central management and control of subsidiaries by employing advanced telecommunications capabilities such as teleconferencing and satellite communications. They also have the capability - and use it - to draw upon information resources worldwide in conducting their business operations. Teleconferencing is gaining importance as a means of marketing, training, and coordinating activities among geographically separated parts of organizations.

### 3.1 Quality of the office environment

The Japanese professionals interviewed have enthusiastically accepted the view that office amenities are a necessary component of intelligent buildings. This philosophy is the foundation for their promotional material as well (see Chapter 10). While traditional offices in Japan demonstrate a limited awareness of the importance of these aesthetic concerns, the new buildings examined were very responsive to them. Several reasons were given for this change in attitude:

1. There is a severe labor shortage in all segments of the economy and attractive work settings are an effective method of recruiting and retaining staff.

2. Women are entering the work force in larger numbers. They are dissatisfied with present working conditions and are not reluctant to make their views known.

3. Foreign travel is quite prevalent among Japanese professionals and managers. This exposure to foreign work settings has led to a demand to upgrade offices at home, which suffer by comparison with counterpart organizations in the United States and Europe.

4. Many foreign companies are now located in Japan, and their offices are judged to be substantially better than their counterpart Japanese organizations.

5. Labor unions now are demanding that the office environments be improved.

### 3.2 Shared Tenant Services (STS)

The design of intelligent buildings in Japan is based on a shared tenant service (STS) concept where services are available seven days a week, 24 hours a day. The STS provides central services purchased by tenants on an as-needed basis. Tenant organizations can select the features they want and their lease agreements and rental payments reflect the services used.

The theory behind STS is that many technologies are quite expensive and can be economical only when used extensively. For example, if individual tenants have their own communication circuit, conference room or high speed copying machine, they will likely be under-utilized. Essential large scale equipment is available for common use by tenants, resulting in advantages due to scale and space saving. Tenants, unable to justify their purchase, can lease the service. In this way, the needs of small and medium size organizations can be "pooled", thereby taking advantage of the latest technologies and their attendant cost-savings.

Examples of these services are PBX-based "least cost routing", data processing equipment, conference rooms, parking, high quality and rapid duplication facilities, emergency power backup equipment, building security and facility management capabilities. Furthermore, a professional staff can provide immediate support when changes are made and problems encountered.

#### 3.2.1 STS problems in the United States

The STS approach was pioneered in the United States with limited success. Several problems led to the mixed results associated with STS in the United States:

1. The "rental of space" and the "selling of building services" has typically been separated. Rental agents often have been reluctant to permit those providing high technology services to work as members of a "rental team". That is, the client is informed about the availability of high technology services after a space rental agreement si signed. Thus, two participants, in what is logically a joint enterprise, have often been at odds with one another. This division of responsibility is consistent with typical building design practices, where telecommunication and information management specialists are often excluded from the design process until after many important decisions have been made.

2. The success of STS has been equated with the presence of an "anchor" tenant, one who leases more than half of the space in a building. Such a tenant, committed to using most if not all of the advanced technological features of a building, can ensure that the costs associated with these systems will be amortized. In the case of a speculative STS building, it has often been difficult to find such a tenant. Large tenants often have technical capabilities that they want to move into the building. Their technology may already be paid for. In the case of computer systems, large expenditures of software and hardware have been made and it would not be economical to "start over again" with new systems with their attendant costs and disruptions.

Even with an anchor tenant, problems may arise. Since the services are shared by all tenants, there is no certainty that when a service is needed it will be available. This is especially important for organizations that rely heavily on communications. Some companies want their own PBX, or comparable capability, because they cannot tolerate the possibility of the unavailability of communications.

3. When only a small number of advanced services are leased, technologies take an extended time to "pay for themselves". Without an anchor tenant, the expenditures for the technologies in intelligent buildings sometimes have made it difficult for STS buildings to compete successfully in the office rental marketplace.

### 3.2.2 STS in Japan

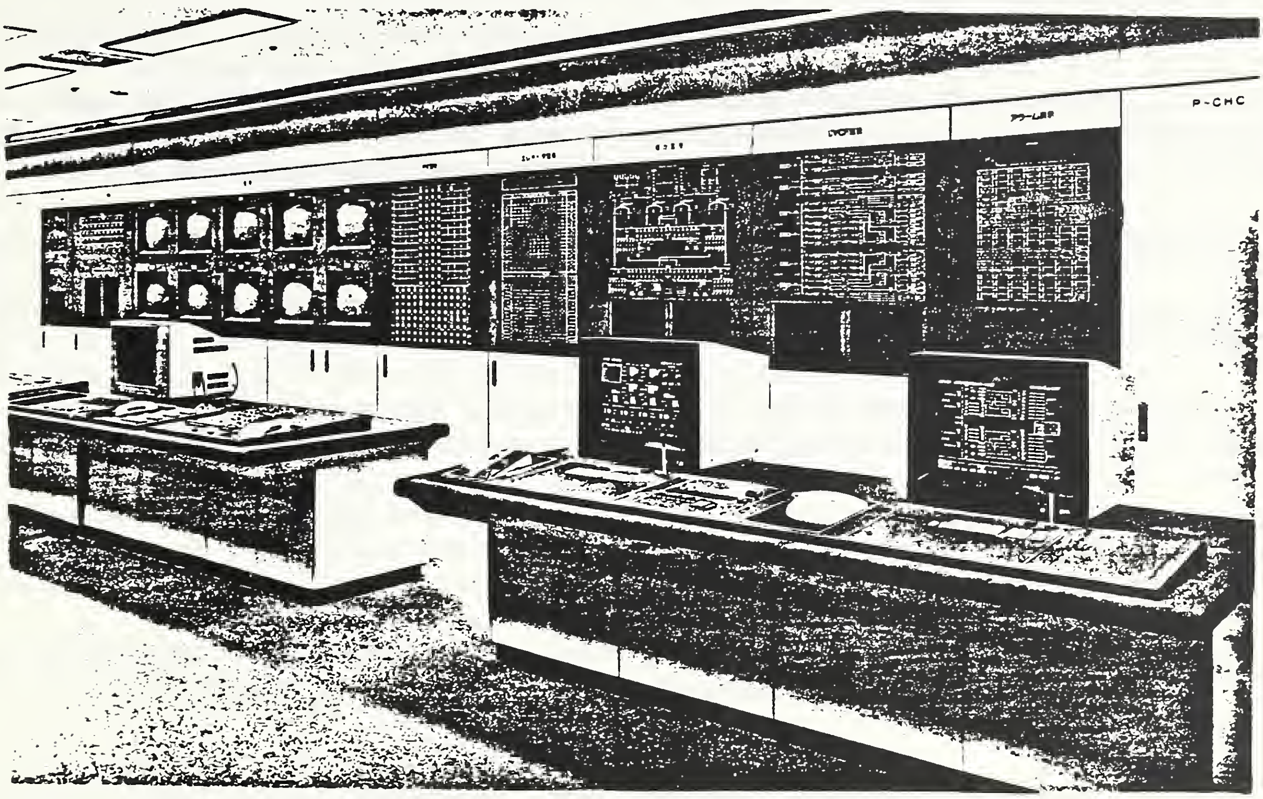
Intelligent buildings in Japan are a relatively new phenomenon. It is too early to determine whether Japanese experiences with STS will repeat those of the United States. The Japanese design firms most active in STS provide a broad range of services to tenants, not limited to technology. For example, Takenaka developed special high quality furniture for one building on the assumption that good furnishings are useful and can help worker performance. Nikken Sekkei has formed a subsidiary for STS, which provides such services as personal service, facility management, building and software maintenance.

### 3.3 Office building technologies

In general, the buildings viewed compared very favorably with those observed in the United States. The quality of construction and finishes appeared to be very high with respect to the exteriors and interiors. The materials used were of top quality and the appearance of lobbies, offices, conference areas and other spaces was quite impressive and attractive. For example, lobby areas were usually of polished granite and marble, and office areas were covered with attractive carpet tiles.

The buildings examined were characterized by an emphasis on aesthetics as well as functionality. The presence of atria in several buildings and a good many plants added to their attractiveness. Furthermore, most buildings had areas set aside for casual meetings, coffee and vending machines as well as physical exercise facilities. The rationale for these places is to provide amenities and places to escape from the "high technology" office environment, thereby averting stress. Another function is to provide an opportunity for

people who work in disparate activities and working groups to become acquainted with one another and to foster cohesiveness in large organizations.



Monitoring Console

The integration of energy management, security, communication, and office automation systems has been just as difficult in Japan as in the United States, for the same reasons. There is little standardization of hardware; manufacturers have unique methods of interfacing systems and use proprietary protocols for software. Their systems often are monitored at a single location, but seldom work interactively. For the most part, they are best thought of as parallel systems that are co-located, rather than being integrated and controlled centrally.

The HVAC, electrical distribution and communication systems incorporate many of the latest technologies available. Microcomputers, linked to variable air volume (VAV) and window management systems, control office temperatures, enabling changes to be made according to the time of day and location within the office, e.g. proximity to windows. Most new buildings have underfloor wiring distribution to workstations, with fiber optic cables used for vertical distribution. Under-carpet wiring is used in many buildings as well.

While organizations in the United States are rapidly moving toward decentralized information processing, making extensive use of Local Area Networks (LANs), their counterparts in Japan have largely centralized their computer operations. While their newest buildings such as Crystal Tower and the Patent Office have them, they are not yet in widespread use. Another reason for the differences in LAN uses in the two countries is that in the United States, they are commonly installed as part of a retrofit activity. In

Japan, retrofitting is much more difficult because of low ceiling heights, and the consequent lack of space for added wiring, often preclude this option. It is more feasible to tear the building down and start over.

As for office automation (OA) technologies, in the United States, word processors (WP) and personal computers (PC's) have been employed in increasing numbers for approximately ten years, while even today, in most Japanese high technology offices, PC's are rare. Computerized operations are performed at terminals associated with mainframe or mini-computers.

### 3.4 Technologies

Among the 'leading edge' technologies seen in Japanese buildings which merit description are:

1. Intelligent cards are used extensively for security, reserving conference rooms, credit transactions, telephone usage and purchases.

2. Earthquake and sway monitoring systems measure building movement and provide information to computers which control roof ice storage systems to counteract building sway.

3. Crystallized liquid ice thermal storage systems combined with natural circulation of the refrigerant, using off-peak power, are employed for climate control.

4. Infra-red sensors employed at workstations to regulate HVAC, lighting and venetian blind movement.

5. Fiber optic systems transmit sunlight to offices and other interior building areas.

6. Teleconference rooms have full capabilities to electronically transmit and receive all types of information in real time - this includes video, data, voice.

7. Robots used are for interoffice document transfer, mail delivery, and facility management activities such as cleaning and inspecting for structural damage.

8. Advanced centralized monitoring and control systems are employed for energy conservation, safety, security, and building management.

9. Fragrances are introduced into offices as amenities.

10. Electromagnetic interference protection systems shelter a building from outside electromagnetic noise, enabling information transmission without cabling.

11. Sunlight and electric light are regulated automatically by a system which alters window blind configurations in conjunction with controlling electric lighting.

Some of these systems will be discussed in more detail below, when particular buildings and technologies are described. (In the case of other systems, such

as the introduction of "fragrances" in offices, no detailed information was provided during interviews or in the printed material supplied.)

**3.5 Comparison of United States and Japanese experiences with intelligent buildings.**

For the most part, the technologies associated with the most advanced intelligent buildings - energy management, safety and security, office automation and communication systems - are similar in both countries.

**3.5.1 Problems with intelligent buildings in the United States and Japan**

The users and managers of intelligent buildings in Japan have encountered many of the same problems as their counterparts in the United States During the planning stage, the population of the building sometimes has been underestimated. After a few years, buildings often house many more people than originally intended. Similarly, the amounts and types of technology and building support systems required have often been underestimated - overall, and on a per-capita basis.

Among the difficulties associated with these inaccurate forecasts are:

1. Insufficient space is available for new wiring. Pulling wire from place to place is very difficult.

2. Temperature control and balancing is very difficult. The density of people and office automation (OA) equipment exceeds the planned design load soon after initial occupancy.

3. People are often crowded into small work areas. Little space is available for personal items and storage of materials.

4. More elevators are needed for the building users.

Upgrading facilities and technologies is very difficult. Product incompatibility and protocol differences are a problem in Japan just as in the United States, with each manufacturer making unique products. No office automation standards exist. Effective systems integration is the primary goal but this appears to be a rather distant prospect. One of the primary reasons for the lack of progress is the need for more effective organizations to support this standardization process. However, both countries are working toward standardization. For example, the Japan Machinery Federation (JMF) has established a building management interface.

Incompatibility of furniture products and systems also make it difficult to design and modify offices and workstations to suit the needs of different organizations and individual workers. Changing existing configurations and/or adding components is often demanding, time consuming and expensive. Trying to combine products from two different manufacturers is even more of a challenge, and is often impossible.

The introduction of automated systems sometimes has produced mixed results. For example, FAX machines sometimes result in short term savings but in the long term, are more expensive than regular mail. In addition, copiers have greatly increased the use of paper.

In Japan and in the United States building systems can pass initial inspection but better facility management is needed to keep the systems operating as designed. Similar problems exist after upgrades and changes. Both countries are trying to merge facility management with design - the concept being to continue to provide services for building occupants after initial design and construction is completed. As systems become more complex, it becomes increasingly important to deal with problems as they occur. Systems to accomplish this purpose are quite expensive, and are not always reliable. The installation of diagnostic systems is often not feasible due to the great nunber and type of possible errors. More accurate and cheaper systems are needed to measure and diagnose building problems.

### 3.5.2 Japanese intelligent buildings

The primary difference between the "intelligent" buildings seen in the United States and Japan is that the Japanese appear to incorporate new technologies as soon as they become available. In the United States, there is a greater tendency to wait until a technology has been "proven" before employing it. The experiences of Takenaka illustrates how one Japanese organization, a leader in intelligent building design, defines the requirements for such buildings:

#### 3.5.2.1 One view of intelligent offices - Takenaka

Six years ago, Takenaka formed a new department for intelligent buildings. They list several features considered desirable for such buildings (15):

"1. Amenity - The working environment must provide mental and physical comfort, including space for general purposes, common use and resting. Workstations should be attractively arranged. A multi-purpose atrium is desirable for relaxation and casual meetings. Dining areas should be attractive. The building should have public spaces with greenery. Several break areas, equipped with vending machines and comfortable furniture, should be dispersed throughout the building.

2. Efficiency - The efficiencies of office functions such as decision making, office work and communications must be improved while reductions in time spent, space, manpower, facilities, energy and overall costs, are sought.

3. Flexibility - This is required for future organizational changes, for upgrading existing equipment and accommodation of new technologies and systems.

4. Convenience - Both manageable office space and easily handled office equipment are indispensable requirements for future offices. Improvements in the potential of individual functions and facilitation of the effective use of these functions are required.

5. Safety and security - The prevention of destruction, alteration of information and data and the unauthorized use of systems is needed. The safety of human lives, properties and buildings is essential.

6. Reliability - Abnormalities should be detected early to prevent trouble, minimize potential harm and promptly restore normal conditions.

7. Ergonomics - The arrangement and improvement of the working environment should be carried out in conformance with the psychological and anatomical characteristics of human beings."

**3.5.2.2 Another view of intelligent buildings - Nikken Sekkei**

Nikken Sekkei, the largest Architectural Engineering firm in Japan discusses intelligent buildings from the standpoint of space features (16):

"1. Intelligent space - where daily activities take place; support is provided by systems, service and operations.

2. Route space - where people, goods, energy, and information flow.

3. Accommodation space - contains goods, energy equipment, and central systems for communication and information."

**3.5.2.3 Design for flexibility - Taisei**

Another leader in intelligent building design and construction, Taisei, indicates how they cope with the need for flexibility in intelligent buildings (17):

"Large open spaces are used, which can be readily divided for any purpose. High ceilings are used to facilitate wiring and other service change requirements. Heavy duty floors are used to accommodate the addition of heavy machines or equipment. Extra space is provided in shafts and machine rooms for future changes. There are also added ducts and wiring space for greater power requirements in the future."

**3.5.3 Some differences between the two countries**

**3.5.3.1 Intelligent cards**

In Japan, "intelligent cards" are used extensively for such purposes as computerized access to areas, facilities, data bases, services such as banking, vending machines, cafeterias, etc. The cards are information storage devices, containing a multitude of information about the individual including where he or she works, job responsibilities and financial data such as keeping account of expenditures and payments. These systems, while available in the United States, typically have limited applications here.

**3.5.3.2 Teleconference facilities**

Most of the Japanese buildings visited have advanced teleconference facilities, enabling participants to interactively exchange information by electronic means. These facilities are used for many purposes such as meetings with

members of the same organization at distant locations, meetings with client organizations and training. Similar facilities are not typically found in intelligent buildings in the United States; they are not yet considered to be cost-effective.

**3.5.3.3 Furniture**

In the United States, workstation design, open office planning and office automation are furniture-based. That is, modular furniture systems permit designers to plan offices in new ways, and to accommodate advanced technologies while doing so. Surveys have consistently shown that furniture quality and functionality are important determinants of satisfaction ratings given by office workers (8).

In many Japanese buildings, furnishings are not yet perceived to be an integral and important design feature. For example, in the Japanese Patent Office, a building designed to be paperless to facilitate the recording and storage of patent information from Japan and other countries, the furniture came from their previous building, much of it more than 30 years old. However, in general, designers and end-user organizations are becoming more aware of the importance of furnishings in intelligent office design.

Electrical systems and telecommunication require changes in the wiring and interface of building and furniture. The general contractor often is responsible for the interface between wire and building. Some furniture systems are designed for the cables to be placed through them, while wiring within furniture is another trend. Separate wires are used for communication, power and information.

When panels are employed, unlike United States offices design practices, they are not typically used for personal workstations but for meeting rooms, refreshment areas, and public spaces. Moreover, most panels are low ones, e.g. 42" high.

**3.5.3.4 "Intelligent" devices; problems**

Two systems are in evidence that are not commonly found in United States buildings. One is a countermeasure against magnetic noises, used to ensure the effective working of electronic equipment. Many of the buildings visited also have sensors to record movement due to wind and earthquakes. Motion detector systems scan all areas frequently, e.g. every 15 seconds.

Two problems with new technologies were cited during discussions. Some buildings have heat and movement sensors to detect the presence of people and respond accordingly. However, the sensitivity of some systems is too great. Users often turn them off because they are activated too frequently by "false alarms". Only 10% of users keep the systems on. These systems respond in an on-off mode, not a variable one, where sensitivity can be changed.

Another difficulty noted concerned the HVAC system control. There is sometimes a substantial difference between the thermostat setting and measured temperature, thereby making thermal comfort control difficult.

### 3.5.3.5 Security

Systems are now available which automatically trigger a burglar alarm sensor at night and are deactivated in the morning when the building is opened. A key card, with an individual code can be used to enter the building during off hours.

### 3.5.3.6 Codes, fire safety

Fire safety regulations are different from those in the United States, e.g. their safety stairs have carpets which cannot burn but can smolder and smoke. For fire code reasons there are vertical ceiling panels to control smoke movement. The code requires fire extinguishers in addition to a sprinkler system.

Codes and regulations prevent furniture from being part of the electrical system. For example, built-in wiring in panel systems are not permitted.

### 3.5.3.7 Quality of public vs private spaces

In several buildings, noticeable differences existed between the building areas used by the general public and those accommodating building occupants. For example, office furnishings and lighting fixtures in public spaces were of a better quality and more functional than those found in employee areas.

## 4. Buildings, complexes, technologies

The following are descriptions of buildings, building complexes, and state-of-the-art technologies visited during the trip. The amount and type of information included varies in accordance with many factors such as time spent, availability of material written in English and technological innovation noted.

### 4.1 Toshiba Corporation Headquarters (1-1 Shibaura 1-chome, Minato-ku, Tokyo 105, Japan)

Construction of this office building was completed in 1984, with 40 floors, a tower, and 3 basements. It is 165 meters high. The total floor area is 147,400 square meters, with a standard floor being 3460 square meters. It was intended as the first intelligent building in the world.

The building was originally designed to be tenant rental space. Toshiba was to occupy part of the building and the remainder was to be leased to others. No plan then existed for office automation. It took more than 20 years to get permission from the local government to develop the building as a waterfront project. The building was constructed in an isolated location with little infrastructure to link it to the surrounding area. Toshiba built the necessary roads and bridges as an investment in the community. During this 20 year period, the overall goal was changed to constructing a company headquarters. The building was redesigned to facilitate office automation which is the foundation of Toshiba's business operations.

Toshiba Corporation Headquarters

The buildings temperature controls are automated and controlled by Tokyo Gas for the Toshiba building and their own building nearby. Temperature regulation is managed by controls in each zone. Energy is provided for blocks of four rooms, and sometimes is difficult to control properly. The amount of power available for use by the building has been increased because of the construction of a new power station nearby. Energy usage was not a major concern when the building was designed.

A centralized control room is used for energy management, safety and security. For example, building zones can be monitored to determine if temperatures are appropriate. If not, changes can be made by an operator if not corrected automatically. In case of fire, users can contact the monitor if necessary. In such an instance, systems operate automatically in accordance with safety procedures, i.e. ventilation, elevators, alarms, etc (18).

Worldwide data and telecommunications are transmitted and received at headquarters from where information is forwarded to appropriate divisions. Toshiba has a private telephone network, linking all domestic plants, branches and sales outlets. The telephone system is computerized, with many features such as call forwarding and numbers stored in memory. The building contains a fiber optic LAN for vertical distribution, coaxial cable for horizontal distribution, and state-of-the-art distributed processing of data. The optical LAN transmits at 100 mbit per second; the coaxial cable at 10 mbit per second. The DP-NET is designed to permit future expansion and technological changes. The on-line OA system links 120 locations through 4000 terminals. They have an electronic phone directory and an electronic mail system.

All operating units have access to the on-line system. Information from the computer is available between 8:30 AM and 6:30 PM to anyone with appropriate access. A distributed processing system is used, and the output can be pictures, graphs, tables, etc. Paper handling is automated by new systems in the information center; on-line data bases are available by means of distributed processing. Optical disks are also used to store information (50k pages) and print out at remote terminals. The data are distributed locally, freeing the central computer for other purposes.

The building contains several specialized areas, including an advanced teleconferencing capability. The reception area contains a computer terminal with a directory listing all employees. The business information center is a central repository, previously stored separately in different departments. It also has a reference corner for employees to conduct research.

The executive conference room is a warm relaxed space, equipped with state-of-the-art audio-visual and computer equipment. At the center rear of the room are high definition 100 inch TV screens with projection units offering stop-frame and graphic features. Each seat has a built-in microphone and speaker. A control console for the room is housed in a desk. It contains two data processing workstations, 2 PCs and a display unit. Conference rooms are reserved by using display terminals located on each floor.

Personal computers (PC's) play an important role in the office. Many of them are connected to a network system and they plan for all employees to have PC's in the near future. (The predominant PC observed was the Toshiba laptop

- a likely reason for their widespread application here and their relative scarcity in the other offices visited.)

Magnetic ID's are used for many purposes; they record the times employees work, pay for meals at the cafeteria and make withdrawals from cash dispensing machines. They also permit security access to restricted building areas and office automation systems.

**4.2 Japanese Patent Office (Kasumigaseki 3-chome, Chiyoda -ku, Tokyo, Japan)**

This building was completed in 1988. It is 81 meters high and has a floor area of 87,900 square meters, with 16 floors above ground and three basements. The standard floor is 3754 square meters.

Japanese Patent Office

The intent of the building is to have an entirely paperless system of patent records within 10 years (1984-1994). 500,000 patent requests are submitted annually, and there is an enormous backlog of paper patents on file. The data are being electronically converted to optical read-only (ROM) disks; Japanese and some foreign patents are available. The project is expected to be completed in five years. Documents can be reproduced and hard copies made; larger and smaller copies of originals can be reproduced. They generate their own specifications for hardware and software to maximize compatibility of information and telecommunications systems.

The building has a large lobby, a glass panel roof, spiral staircase and numerous plants - making it a very inviting and attractive space for visitors and employees. People walk outside and around the space to experience a change in surroundings. The roof has an exercise area. The lower lobby contains a coffee break area and there is a lounge on the 16th floor for relaxation. A central courtyard provides visibility between offices and daylight for interior spaces.

Larger than average elevator hallways are on each floor. They face the windows and serve as break areas. Information boards and telephones are available for visitors, who can contact appropriate personnel when assistance is required. People are met in the reception area because there are public and private cores in building. (Some activities performed in the building are confidential in nature.) Research rooms are also available for use by the general public when making unaided patent searches - without the assistance of patent office personnel.

The standard floors, from the 2nd to the 16th, have two major sections: two office areas, each 1200 square meters, to the south and north of a central courtyard and two core sections, east and west. The rooms are designed as large open areas without partitions to promote flexibility. The windows are can be opened manually and the upper part of the panes are coated to prevent glare on VDT screens. The offices have a double-decked raised floor (15cm high) for power, telecommunication and LAN systems. The computer rooms have double decked raised floors 50 cm high. The "core" building systems are located at the perimeter.

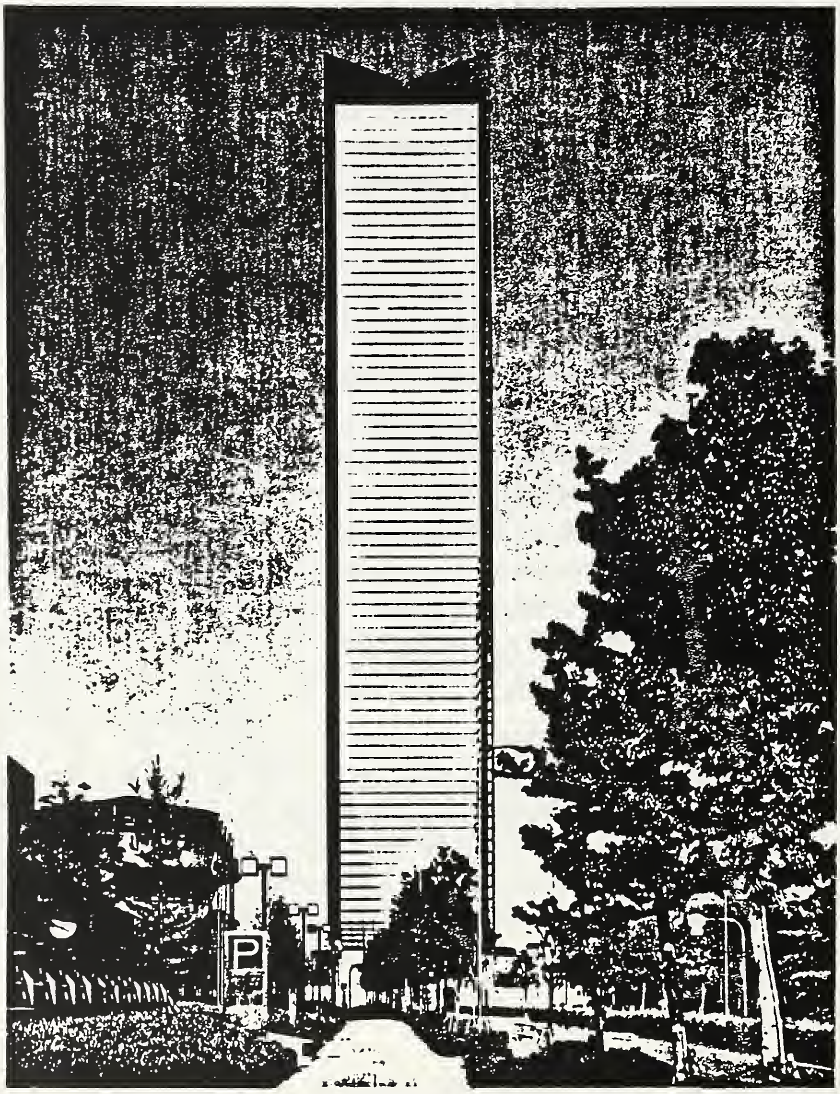
The building is cooled during the winter as well as summer. The air conditioning system works by dividing the entire area into 40 square meter segments, each with its own temperature controls using a variable air volume (VAV) system. Staff members deal with any problems identified. Steam heating is supplied by an adjacent regional heat supply facility. Backup air conditioning is supplied for the computers. Two emergency backup power systems are available; one for the computer center, the second for other building systems.

A central control office is in the basement, which monitors such systems as security, energy usage and elevators. An electronic display system shows temperatures for the 20 building zones. The operator monitors and controls temperatures by means of a VDT screen and a light pen. The monitoring system also displays temperature data for the various zones into which the building is divided. Daytime and nighttime temperatures also can be charted.

An executive conference room is used for briefing purposes. The blinds are controlled automatically and by remote electronic control. Blind management in the room is used for daylighting, aesthetics and energy saving. Blinds always are closed when the room is in use (19).

### 4.3 Crystal Tower - under construction (Osaka Business Park)

This building was still under construction when visited, and contains many of the latest available technologies. It is 150 meters high, has 39 floors - two below ground. The rental floor is 1250 square meters, with room units of 410 and 430 square meters. Normal building height zoning regulations were waived. By providing more public space, the designers were able to build higher, thereby increasing the building volume permitted.




Crystal Tower

The Crystal Tower is located in Osaka Business Park. The entire area was devastated during World War 2. The area is being redeveloped for the first time since the war. The site includes ponds and fountains to give the appearance of a waterfront. The lower floors are designed with lofty open spaces for artistic, international and cultural events. Scenic views are available in several directions. For example, Osaka Castle, a national historical landmark, can be seen nearby.

Seventy-two percent of the space is for lease. Office floors are designed using a standard module of 3.6 square meters rather than the typical 3.2 square meters found in Japanese buildings. Ceilings are 2.8 meters high instead of the traditional 2.6 meters, to create a feeling of expansiveness. Pillars are 7.2 meters apart. A flat cable system distributes wire to workstations, allowing flexibility. The data are carried by an optical LAN system. The exterior is covered entirely by glass developed in Japan with 27 percent transmission and 32 percent permeability. An unmanned moving gondola is used to clean the windows.

The lighting and HVAC systems are closely integrated, and both depend upon advanced technologies employing computerized controls and manual backup systems. There are sensors on top of the building to control blinds based on the light intensity. The perimeter based air curtain works in conjunction with blinds to control temperature and lighting. The air conditioning module size depends on location; the size in the interior being half of that near the windows. The blinds are initially controlled automatically by roof sensors. Changes in temperature are controlled by a central computer. The remote controlled electrical and mechanical systems allowed the building to be divided into many zones, controlled by a VAV system. Each tenant can modify lighting, temperature and blind positions by a wireless infra-red control system. The usage and costs for each area are compiled and data made available to tenants and building management.

Air conditioning is provided by a "vapor crystal system". Ice crystals are formed during the night when electrical rates are low. Natural circulation of R-22 refrigerant, for which no circulation motor is needed, is employed to distribute the stored coolness in the ice storage system. Nine ice storage tanks are on the roof, which also serve as vibration and movement controls. If the building sways, the computer controlled tank moves in the opposite direction to counteract the motion. Another benefit of the system is that less duct space is needed for air distribution because of the lower air temperature made possible by the lower refrigerant temperature as compared to traditional systems.

An identification card system is used for a variety of purposes. A person entering and leaving the building is automatically recorded. When a person enters the building, the blinds open and the lights go on. When he or she leaves, the systems shut down. The lights are activated according to pre-coded information, identifying the individual's workstation. The card also is used for banking and automatic vending machines.

Cafeterias are at the mid-level and top floors. On the second basement floor is a fitness club including a gym and pool. The elevator area acts as a foyer as well. A business support center and teleconference room is available on the 20th floor. The second floor has a shop for office supplies of all kinds.

Hallways are designed for breaks away from the office. The bathrooms are well furnished and first class.

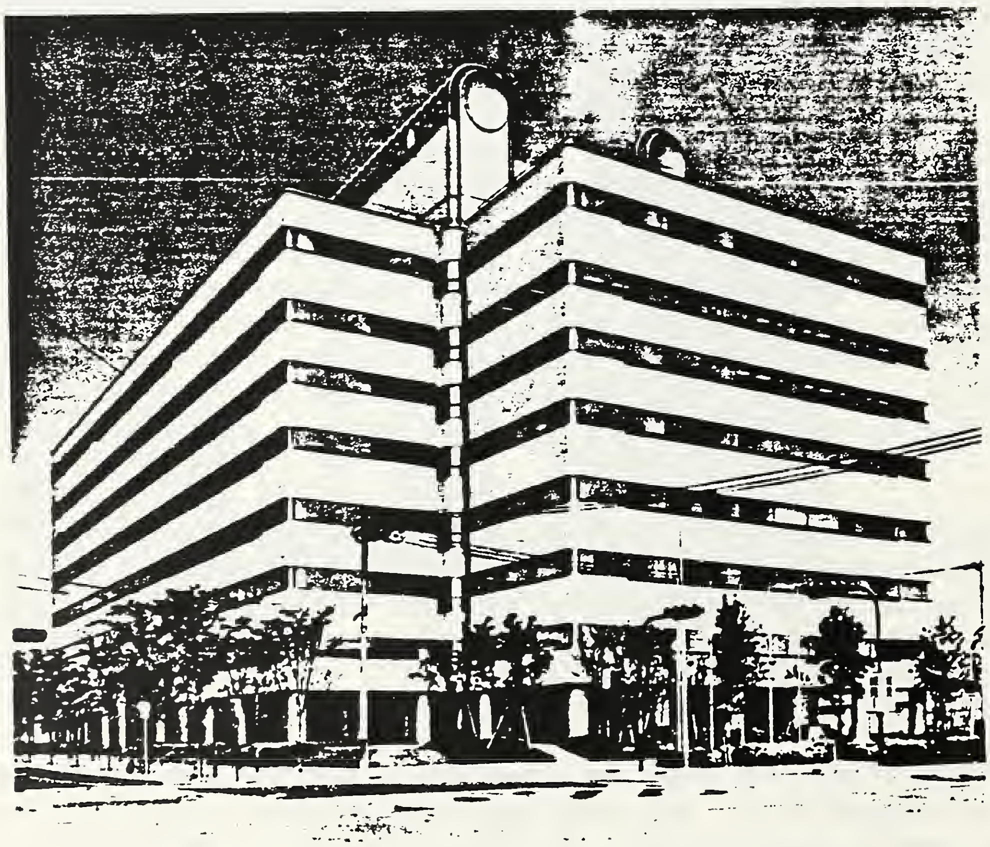
All facilities are owned by the building proprietor. A variety of building and office automation services are provided, e.g. furniture designed for tenants. A questionnaire survey is used to obtain information from the tenants to improve services. The first part of the study based on the survey was performed during the summer of 1990 (20).

### 4.4 Fujitsu Kansai Systems Laboratory (2-6, Shiromi 2-chome, Chuo-ku, Osaka 540, Japan)

The building, located in Osaka Business Park, has eight floors above ground and a basement. The total floor area is 32,500 sq meters. Completed in 1986, it is owned by Fujitsu. About 1200 system engineers work in over 20 research laboratories, including AI, computer graphics, and manufacturing.

The laboratory provides customer support for the Western Japan district, encompassing one third of Japan. The firm has two support centers, one in Tokyo and the other in Osaka. (High speed telecommunications systems link computers in the two cities.) Another function is the generation of system engineering work. The facility also serves as a demonstration center aimed at end-users and managers, showing the latest Fujitsu systems in operation.

Finally, the building is used for educational purposes. The education provided ranges from introductory to highly specialized courses, with emphasis on practical training. All educational materials are produced internally by Fujitsu.



Fujitsu Kansai Systems Laboratory

In the past individuals have performed systems engineering work. However, the nature of the work has changed as it has become increasingly complex. Software is now developed by large teams for centralized systems, and smaller groups for PC applications. With more engineers in the building, and the greater need for interaction among individuals and groups, communication facilities need improvement. These factors underlie the need for improved space.

Business functions are divided into integrated zones - research on software technology, an office automation (OA) showroom and top-floor seminar rooms for training. The structure consists of a customer zone from the 1st to the 4th floor where visitors are welcome. Above the 4th floor is an internal zone where research and development is conducted. The top floor has accommodations for people from out of town who are attending long seminars. A range of classes is available for building tenants, ranging from an introduction to computers to the advanced use of systems.

Different organizational functions are performed on each floor. The eighth floor demonstrates how computers are used in all corporate activities. The 6th and 7th floors contain systems engineering state-of-the-art research facilities. The 5th floor has two mainframe computers used for information access and program development. The 4th Floor is a general purpose floor. It has a conference room for 300 people, is outfitted for conferences and seminars and houses a general cafeteria. The 3d floor shows the communication system of the future, with the latest technologies, OA and other equipment. Visitors are encouraged to try to use the systems in the customer zone. The buildings all have showrooms on the first floor as part of the leasing agreement to encourage visitors. Fujitsu, NEC and the power company, are all part of the same park.

The general office areas have a traditional layout with no partitions and a "bullpen" arrangement. Low partitions are provided for those engaging in research. There are only 20 private offices are in the building. Fujitsu has an office service center for printing, binding, mail, document ordering and communicating electronic information.

The building's features include an electronic conference system, a LAN and other advanced systems for information processing, materials handling and telecommunications. It has an automatic mail delivery system using robots. Mail for each organizational unit is placed within a pre-programmed robot. The robot "recognizes" the destinations for the mail by means of locational codes in the floors of the building. Mail for a unit is then manually removed from the robot, which then moves to its next destination. A centralized computer system is used to control such items as building security, HVAC, energy usage and safety systems.

Intelligent cards also are extensively employed for access to specialized spaces, cash transactions and building entry. For example, individuals are authorized to enter a conference room at a given time. This information is coded in a computerized lock. When the individual places his or her ID card in the lock, if permission has been granted, the lock will open, if not, entry will be denied. Access coding is centrally controlled to ensure eliminate conflicts among different groups scheduling facilities simultaneously. Similarly, ID cards

enable authorized personnel to work "after hours", enabling them to enter the building and areas within the building.

Teleconferencing is important now and is becoming more important to Fujitsu's business operations. They have 25 major teleconferencing centers, one in the United States, in San Jose, California. Teleconference facilities are equipped with some of the latest technologies. For example, the camera focuses automatically on the person speaking and is triggered by voice. Material written on an electronic board is shown on local and remote monitors.

Fiber optics are used for vertical wiring. This includes access panels with two standbys for horizontal distribution. The riser shafts are wider than normal and other spaces also are enlarged to accommodate more wiring and facilitate future moves. Safety and security wiring are separated, to conform with building standards, laws and codes.

The 6th and 7th office floors are non smoking areas. Separate smoking areas are set aside on other floors. The supervisor determines where smoking is allowed. The cafeteria has a 'no smoking' policy. Smoking areas have large capacity air conditioners (21).

In the design process, the needs of Fujitsu were identified by a group of end-users, shown to Nikken Sekkei (the design firm), who translated them into building requirements. A primary design goal was for the building to be responsive to the needs of end-users - operational and environmental. Users were given major responsibilities in defining building operations. The tenant organizations know their hours of operation and special requirements better than facility managers and were given were able to incorporate their own criteria into building operations. An important design goal was to combine business needs and amenities desired for every day living. Aesthetic and comfort considerations played an important role in the final office design as well as the public spaces within, and outside of the building.

### 4.5 IBM Japan, Hakozaki Office (19-21 Nihonbashi Hakozaki -cho, Chuo-ku, Tokyo 103, Japan)

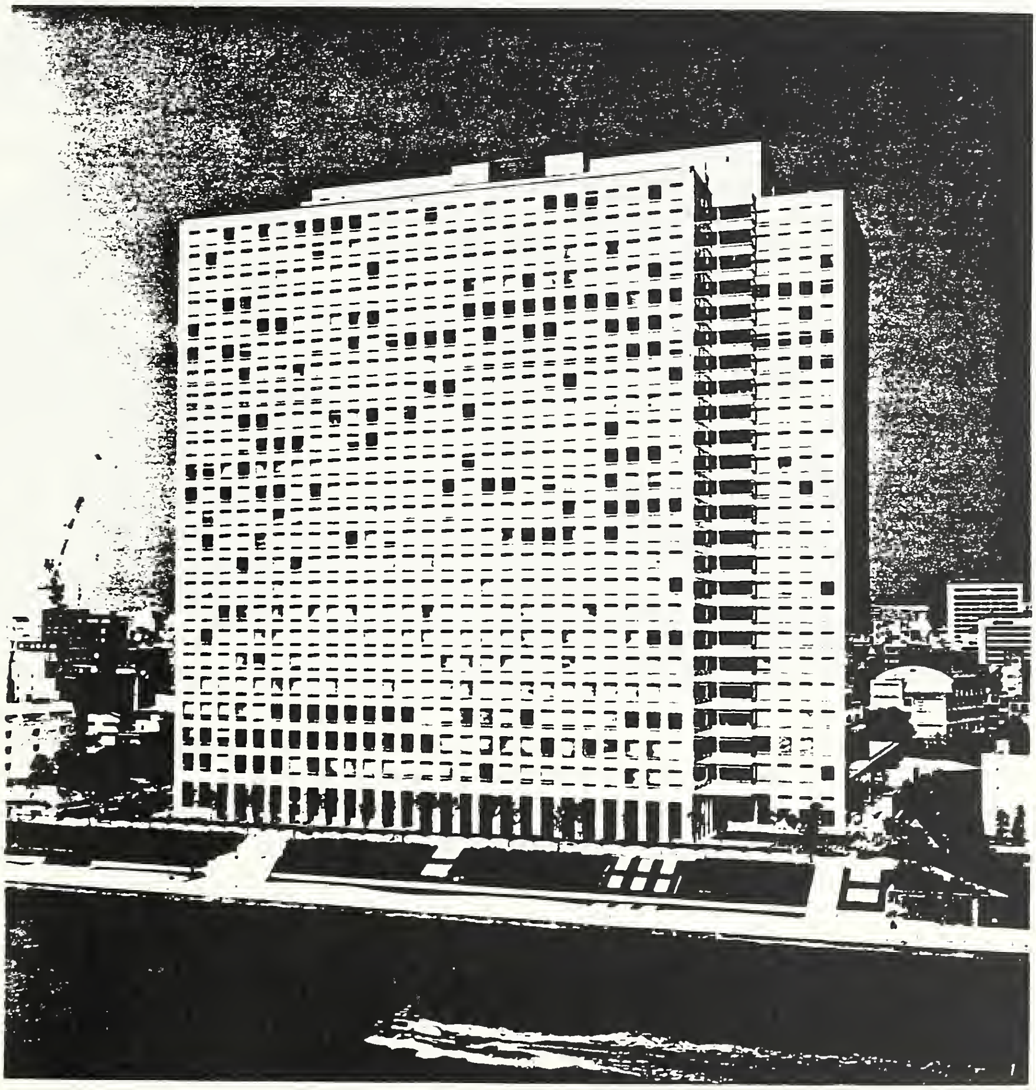
The Hakozaki marketing office is IBM's major sales office in Tokyo. It houses 5000 people, comprising their sales staff and supporting personnel. It is 25 stories high and 100 meters high. The total rentable space is 83,000 square meters, and the typical floor has 3300 square meters of net usable space.

The building houses marketing people, who are at their desks only 30-40% of the time. IBM rejected the concept of "one person, one seat" in favor of a system where a workstation was shared by the group. The system is flexible enough to cope with staff additions and changes in group membership. Above all, the desire was to provide ample desk space for each person. For example, if 50 workstations are to serve 75 people, then the space allotted for each one can be 50 percent larger than would be the case if workstations were provided for all 75 workers.

The telephone system is designed so that the person first selects a workstation location and the telephone number at the desk is changed to that of the occupant.

Noticeable in the building is the difference between the space used by the employees and the space used for meeting outside clients. The meeting spaces were furnished better, more spacious, and generally more attractive. For example, the lighting fixtures in the general office space are bare bulb fluorescents, while those in the "public" spaces had prismatic lenses.

The building has several areas outside the office spaces equipped with vending machines and sofas for people to relax and get away from the work floor. However, it was quite evident that these areas are not used much. The explanation given was although the building was designed to provide these amenities, the IBM culture does not encourage their use. Employees do not feel free to spend time in them because they did not appear to be "working" (22).



IBM Japan, Hakozaki Office

## 5. Building complexes.

The next topic to be covered are intelligent building complexes. Ark Hills is the first of this kind of complex, and Makuhari Techno Garden is the latest, and perhaps one of the world's most ambitious example.

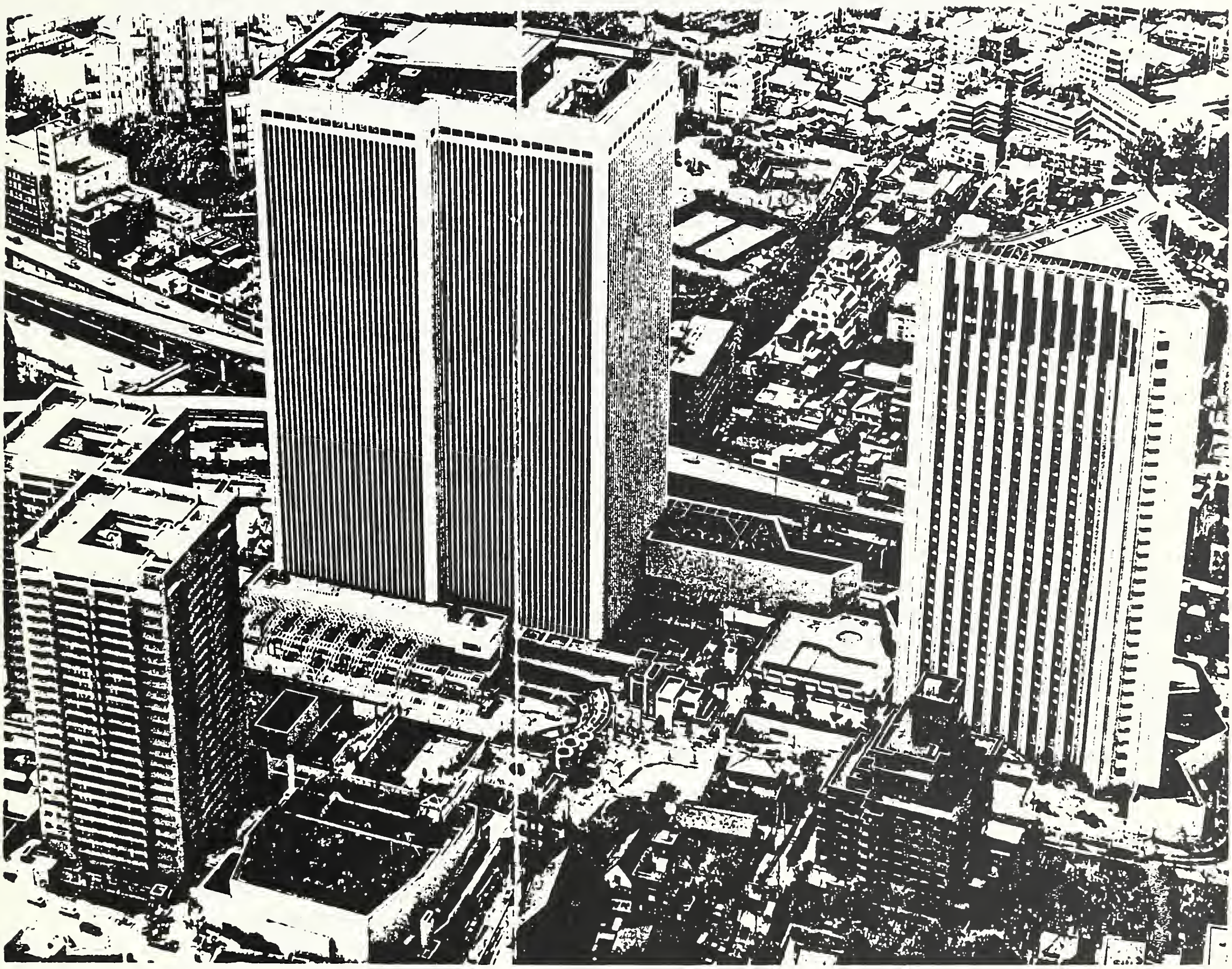
### 5.1 Ark Hills (12-32, 1-chome, Akasaka, Minato-ku, Tokyo, Japan)

Ark Hills is an integrated complex of buildings in Tokyo, including offices, residences, a hotel, a television studio, a concert hall, community facilities and plaza. The complex is intended to be a model for the new Tokyo, incorporating business, recreation and living accommodations in an attractive setting. The developer hopes that Ark Hills can function as an "open university", demonstrating a life style and culture for the future. The community facilities, for example, are intended to be used for adult education as well as for many other activities. Public functions are planned for the plaza as well. The office buildings (twin towers) are 153 meters high, and have 37 above ground floors and four underground. The total floor area is more than 180,000 square meters.

The heating system uses chilled water and steam from an on-site energy plant. Air conditioning units are on each floor for the interior zones; the perimeter zones also have an air balancing unit. The building control system has four major zones controlled by a VAV; a zone is 600 square meters and contains approximately 34 work stations. Standard temperature is 24.5 C, and is controlled centrally. Usage of equipment and services are tracked for billing purposes - air conditioning, utilities, electricity and water. Rainwater is recycled.

A sunlight collection and transmission system (Himawari) is used to enliven many areas of the complex and to provide the lighting needed for trees and plants in several locations (see 6.1 for a detailed description).

The safety and security system monitors building areas by closed circuit TV, and enables interaction with various building systems. For example, in the case of a fire, the system shows its location and then acts automatically to control air flow, elevators and notify the fire department. The operator can telephone the areas affected. Alarms are automatic on the fire floor and on the floor above and below. The person in charge of fire safety contacts the operator to confirm the presence of fire. Fire drills, including building evacuation, are conducted twice a year. Recorded announcements also are possible. However, the range of possibilities is great, making operator intervention important. For example, a varied series of announcements are pre-recorded in case of an earthquake, the message differing depending on the severity (23).



Ark Hills Complex

### 5.2 Makuhari Techno Garden (MTG) (23-9, Ginza 1-chome, Chuo -ku, Tokyo 104, Japan)

MTG is in the Makuhari new business district, opened in 1990, it is located 30 miles west Tokyo; in the Tokyo Bay area. The total population of the complex is expected to be 150,000 people. A central power plant will serve the entire area. Housing will be provided for 26,000 people; those who live in the community are expected to work there but Tokyo commuters also are anticipated. Development will continue into the next century.

MTG is an example of the Japanese desire to move activities away from Tokyo, which is extremely central to Japanese business life. It is an early step in a general decentralization process. However, satellite offices are not yet popular because people want face-to-face meetings and most large organizations maintain offices in Tokyo. Employees in satellite offices often have a sense of isolation.

The centerpiece of the complex are twin towered intelligent office buildings, more that 100 meters high, with a total floor area of 215,000 square meters. Between the twin towers is a 2000 square meter atrium with many plants and shrubbery that is designed for relaxation, conversation and informal meetings. Facilities will include a swimming pool and an athletic club. An international conference center, hotels, R&D facilities, shops, and a residential area are also planned. MTG is advertised as an alternative to Tokyo's high cost and pollution.

Each floor in the twin tower building covers 2,700 square meters, including 700 meters of common space. Each wing on a typical floor is 1000 square meters with options available for purchasing or leasing. The MTG information communication system exchanges information via the OA host computer with individual tenants, an IC card gate, video information and other terminals, funnelling voice, data and video traffic in a real time mode. Related systems include a central monitoring system, a machinery security system and a digital PBX.

Video information is provided to visitors and tenants at eight points in the building. Terminals access tenant terminals by means of telephone lines to permit contact with receptionists or the individual to be visited. Other available information deals with buildings, facilities, transportation and MTG services.

The telephone exchange system is a part of the STS. A digital private branch exchange (PBX) has 1,020 public lines, 6,000 extensions; services include international subscriber dialing, speech level control, extension number addition, tenant master telephone, abbreviated dialing, transfer, teleconferencing, facsimile (FAX) accommodation, paging, line lockout, bill logging, least cost routing, 2000 planned electronic mail boxes, etc. The system maintenance includes traffic measurement, fault display, online data generation, periodic testing of circuits, fault transfer.

The buildings are linked together by a LAN system. A comprehensive system exists for monitoring energy usage and security for the entire complex. The computer system network provides automatic building management and tenant services by means of an optic-fiber office automation LAN.

The corporate information management system includes owner support services such as charging, and private information needed for card system management stored in a single OA host computer data base. Information on charges is automatically collected on all peripheral devices and bills prepared.

Information services include electronic mail, an electronic message board, electronic mail maintenance support, file management support and document processing. A tenant wishing to reserve a common facility designates a facility and date, and makes reservations through a terminal, using an IC card for access. These data are stored and verified by computer.

All activities associated with the IC card are managed from the control center, including issuance of cards, entry modification, accident registration and card cancellation. The system manages the entry and exit of individual tenants through the rooms that they control. This is accomplished by IC cards or key boxes. Information is stored in the host computer and transferred to the security system as required. Elevators are interlocked when a space is unoccupied and all common facility lights are turned off from the central monitoring system.

Rooms are individually air conditioned after hours by means of an online reservation system accessed through tenant terminals. Extra hours are billed automatically. IC cards also are used in dining rooms, cafeterias, shops and vending machines. Payments can be prepaid or postpaid.

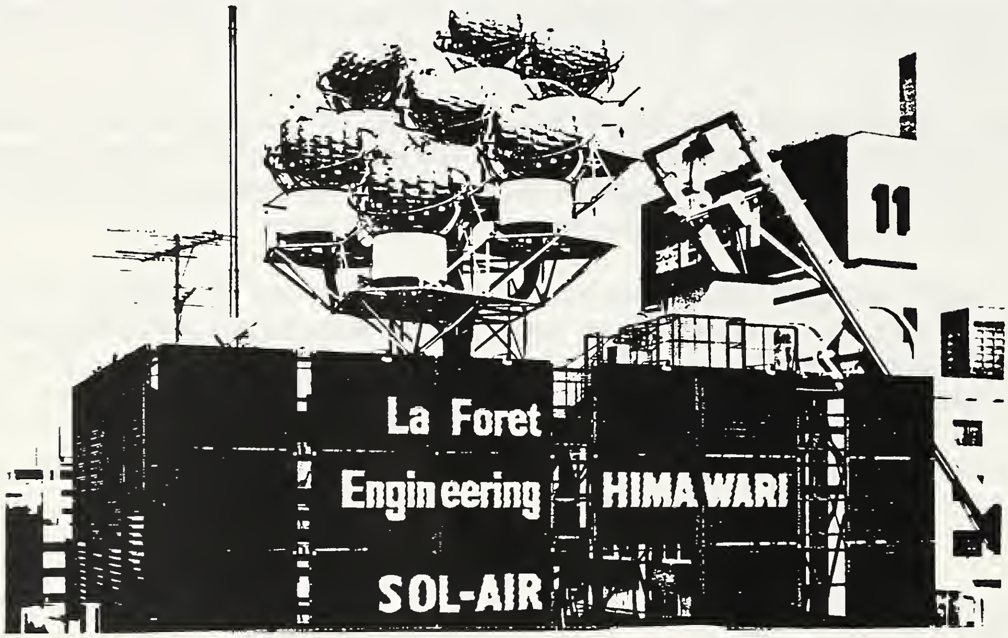
Shared video conferencing capabilities are present in the building, but not yet operational. They can be connected to local CATV networks. TV conferencing is planned for installation in rented conference rooms and will be part of an integrated services digital network (ISDN) system (24).

## 6 Technologies

The following systems illustrate some of the advanced technologies in use in Japan. Similar systems can be found in intelligent buildings in Europe and the United States.

### 6.1 "Himawari" System - Sunlight collection and transmission

The Himawari system is a sunlight collection and transmission system. It collects sunlight by means of Fresnel lenses, removes most of the harmful infra-red and ultraviolet wavelengths, and transmits this light via optical fibers to wherever it is needed. The system uses an internal clock mechanism to calculate the position of the sun and move the system in its direction on a cloudy day. On a clear day, the exact location of the sun is determined by a sensor. The system, present in Ark Hills, is used to light atria and office areas with natural light and foster growth of plants and trees indoors. Light can be transmitted up to one kilometer. However, cable costs are still quite expensive.




Himawari Solar System

A "light sauna" has also been designed as a relaxation area. Workers can make use of the facility to refresh themselves (25).

### 6.2 "Sol-air" Heat Pump

The Sol-air heat pump utilizes black aluminum panels, incorporating an air heat source screw compressor. It works with a refrigerator system and has a primary storage tank containing hot water or ice and an auxiliary tank for hot or chilled water. The system produces and maintains hot and cold water all year round.

In the summer months, water in the main tank is decreased from 20 degrees C to 10 degrees C in the course of a day. The temperature in an auxiliary tank, about 1/5 as large as the main tank, is increased from 20 degrees C to 70 degrees C. In this process the air is cooled by an absorption cooling system (the heat is removed from the hot water stored in the auxiliary tank). At night the heat is discharged through the solar panels.

In the winter, the system is operated in reverse. The Sol-air panels are used in the daytime, when there is sunlight. The panels can be warmed in the sun to 20-30 degrees C. Water in the main tank is increased from 20 degrees C to 70 degrees C and used for room heating (26).

### 6.3 Crystallized Liquid Ice Thermal Storage System (CLIS)

" A dynamic CLIS can continuously generate, transport and store fine ice particles. When combined with a heat pump, the system can heat water or space, while simultaneously generating ice. The combined system is termed CLIS-HR can meet all air conditioning needs.

By using Freon gas R-22 and utilizing latent heat transfer and applying the principle of natural refrigerant circulation, the system provides decentralized and dedicated climate control without secondary water circulation pumps and compressors, needed in conventional systems. When combined with the ice storage system, which can use off-peak, night-time power service, the power demand can be balanced. The initial cost of the system is comparable to that of conventional ones, while the running cost is about one third as much." (27)

"The cooling heat transportation capacity of the ice and chilled water mixture transportation system is about six times as large as the capacity of a conventional system (when the ice packing factor (IPF)= 25 percent.

The diameters of piping for the ice and chilled water mixture transportation system can be reduced to about 40% of those for a conventional system.

The power consumption of the pumps can be significantly reduced by using the system. The initial and "running" costs of the system are comparable to chilled water and non-chilled water storage systems.

The frictional resistance of piping for the system is increased by 20-30 percent, compared with that of a conventional system." (28)

### 6.4 Robots

Ohbayashi employs robots for a variety of construction, diagnostic and maintenance tasks. One is devoted to ensuring that "clean rooms" are properly maintained. It uses a guidance system composed of a TV camera and pre-

positioned reflectors. As it moves, the robot performs pre-programmed inspection and monitoring routines, monitoring leaks and particle count with its sensor arm. It is said to produce only 1/10th the contamination caused by a person performing the same job.

Another robot was developed to automatically inspect reinforced concrete walls for weathering and weakness. The robot's vacuum-cup tractor treads cling to walls and ceilings, permitting it to move freely. It uses ultrasonic waves and TV cameras to inspect wall finishes for cracking and other signs of weathering and deterioration. A third robot is used for smoothing concrete and for cleaning. It is guided by a laser beam, and consists of two major components, the carrier vehicle and the operation machine. This design enables the operating portion of the robot to be changed, and perform a variety of different tasks. It is claimed that all of these systems reduce the time needed to perform tasks, and enhance the quality of the final job. (29)

As mentioned in Section 4.3, Takenaka, in the Crystal Tower building, employs robots for mail distribution. Each destination in the building is pre-coded in the mail room, and the robots deliver materials with minimal human intervention. The robots move along "tracks" hidden in the floors.

# 7. Summary of observations

## 7.1 General - Japanese office design

One of the most intractable problems faced by the Japanese is limited office space. One method of overcoming this difficulty is that used by IBM Japan. In an office where staff members are at their desks only 30-40% of the time, they have instituted a system of shared workstations. Employees are not assigned to a particular desk; instead they use the first available one. Each workstation can thereby be larger and better equipped than it would be if every person had his or her own desk. A personal identification system and movable files enable people to work anywhere.

The Japanese are trying to upgrade their offices by providing more space, larger desks and low partitions (1 meter) which provide some privacy, and still enable conversations among co-workers and supervisory visibility. More terminals and PC's are being introduced into workstations. Their latest systems have overcome the problem of automating Japanese kanji symbols.

## 7.2 Environmental Systems

### 7.2.1 Acoustics

While noise and lack of privacy are among the major complaints of office workers in the United States, acoustics is not yet a primary consideration in Japanese offices. Tradition, in office and home design, undoubtedly plays an important role in setting priorities. Because of space restrictions, the Japanese people have had to adjust to crowded conditions at home and at work. Most offices are totally open, and when partitions are used, they are typically low (36") and produce little if any sound attenuation. Also, primary noise sources in the United States - impact printers and copiers - are not yet abundant in Japan.

### 7.2.2 Lighting

Lighting seems to have a low priority in many new buildings. Bare-bulb fluorescents are widely used. To make matters worse, lighting levels are very high in Japan, causing many glare problems. Built-in task lighting is used only occasionally because the workstations do not have high partitions. Task lights from one workstation creates difficulties for neighboring locations, and is therefore discouraged.

Natural lighting is provided by atria and balconies whenever possible. In several buildings, natural and artificial lighting systems are integrated by using light sensors which automatically switch off lights when daylight is sufficient for visibility. Sensors also are used to control venetian blinds, which are activated when the sun becomes a glare source.

### 7.2.3 Air quality

Air quality is becoming an important design factor in Japan, as it is in the United States. In both countries, non-smoking regulations and practices are common. For example, in the Fujitsu building, the 6th and 7th office floors are non smoking areas as is the cafeteria. Separate smoking areas with large

capacity air conditioners are set aside for smokers. On the working floor, the supervisor determines where smoking is allowed. Fragrances are being added to many new Japanese buildings; in the United States, there is some work being done in this area but it has not proven successful yet. Table 3 below indicates environmental conditions required by the Japanese Maintenance Code.

| **Table 3 Indoor Environment Required by the Building Maintenance Code in Japan (30)** |
|---|
| 1. Airborne Particles 0.15mg/m³ max |
| 2. CO <10 ppm |
| 3. CO2 <1000 ppm |
| 4. Room Temperature = 63 degrees F - 83 degrees F |
| 5. Relative Humidity = 40-70% |
| 6. Va (Air Velocity) = 1.6 ft/sec |

**7.2.4 Individual environmental control**

Japan and the United States are both trying to provide more individual control to the operator of environmental systems such as lighting and HVAC. In the United States, Johnson Controls has developed a system [(Personal Environmental Module (PEM)] for individual control of temperature, air movement and lighting and is now marketing the product. Japanese companies have identified the need to control environmental characteristics for individual workers, and are developing systems to meet this requirement. For example, individual lighting and temperature controls at the workstation are being studied by Nikken Sekkei.

## 8. Organizations performing intelligent building research

In addition to the Construction Management and Architectural Engineering companies designing and building intelligent office buildings, several organizations are actively involved in promoting and/or performing research on this topic.

### 8.1 New Office Promotion Association (NOPA)

NOPA was established in 1987, under the auspices of MITI. Their function is to promote increased comfort and functionality in new offices and facility management. They had 40 sponsoring organizations and 247 corporate members as of April 1990. NOPA engages in three basic activities (31):

1. Human development; training for facility managers and office designers; instituting facility manager qualification system; conducting inter-industry seminars and coordinating with other similar institutions in Japan and abroad.

2. Publicity; publish a monthly newsletter; award outstanding offices; organize trips to "leading edge" offices, organize symposia and seminars.

3. Research; topics include: comparative studies of Japanese and foreign offices, improvements expected by including intelligence in buildings, preparation of office design guidelines, studies of office renovation and changing furniture.

The following table describes NOPA's approach to intelligent buildings.

Table 4 NOPA Description of Intelligent Office

| BASIC SYSTEMS | |
|---|---|
| OA & Communications | Building Automation |
| * Digital PBX<br>* Local Area Network<br>* Satellite Communication<br>* TV Conference System<br>* Closed Circuit TV<br>* Flexible Wiring System | * Operation Management<br>HVAC, Lighting, Transport<br>* Conservation<br>Energy, Manpower<br>* Security Control<br>Fire, Crime, Data, Access |
| **EXTRA** | |
| Identity & Amenity | Office Service |
| * Status, Individuality<br>* Space Planning<br>Modularization, Atrium, Lounge<br>* Refreshment<br>Cafeteria, Fitness, Clinic, Greenery<br>* Air Quality, Odor, Temperature-Control | * Information<br>* Stationery Supply<br>* Print, Word Processing<br>* Consultation<br>* Renew, Remodel, Removal |

### 8.2 Japan Facility Management Association (JFMA)

Forty members constitute the sponsoring group, comprised of major enterprises and individual members. About 120 organizations and 125 professional members have joined since its founding in 1987. JFMA is affiliated with the International Facility Management Association (IFMA).

JFMA has established a working relationship with the MIT Architectural program, where it sponsors courses in facility management for Japanese organizations interested in training their staffs in this discipline.

Buildings are studied and monitored under the guidance of Ministry of Construction. JFMA also conducts lectures at educational institutions and publish a newsletter, which offers opinions and describes new facilities.

### 8.3 Delphi

Delphi is a private company which publishes and translates books and other materials dealing with building design and use. It developed a CAD system for building design and operations and performs CAD service for clients. Delphi conducts seminars on Architectural Engineering Control (AEC) systems and sponsors AEC conferences in Japan. Finally, they arrange tours for Japanese designers, engineers, facility managers and other building professionals to the

United States and Europe dealing with issues such as intelligent buildings, interior design and facility management.

### 8.4. Nippon Telephone and Telegraph (NTT)

NTT has two subsidiary organizations which perform intelligent building research - NTT R&D and NTT Building Technology Institute (NTT-BTI). NTT has formulated a comprehensive plan for intelligent building design and implementation, as detailed in Table 5.

**Table 5 NTT Technologies Supporting Building Intelligence**

| | Office Automation | |
|---|---|---|
| * LAN construction | * Text processing | * Decision making process support |
| * Schedule control and support | * Information management | * Office task processing |
| * Online services | * CAD and CAM | * Public-oriented information services |
| * Software support | * External data base access support | |

Table 5 NTT Technologies Supporting Building Intelligence

| Building Control Systems | Security Systems |
|---|---|
| * Optimal control of heat source and air conditioning facilities | * Video observation |
| * Automatic control of temperature and humidity | * Entry Control |
| * Operation and control by schedule | * Tele-locking control |
| * Control of intake air | * Fire detection, alarm, extinguishing control |
| * Elevator bank control | * Smoke control and automatic evacuation |
| * Elevator voice response control | * Gas leakage detection and alarm |
| * Monitoring of building environment and facilities status | * Water leakage detection |
| * Energy consumption metering and billing | * Automatic monitoring of fire protection |
| * Telecontrol | * Earthquake response |
| * Automatic parking control | * Power failure response |
| **Energy Saving Systems** | **Telecommunications** |
| * Automatic lighting adjustment and om/off adjustment | * In-building telephone system and PBX |
| * Centralized automatic blinds control | * High speed digital data transfers |
| * Energy management | * Memo-pad communications |
| * Water efficient hygienic | * Elecronic mail |
| * Solar energy power supply | * Video conferencing, voice messaging |
| * Outdoor air cooling | * Graphic communications-moving, still pictures |
| * Heat reclation for air conditioning | * Satellite communications |
| * Automatic small zoned controlled air condtioning | * Teleport systems |
| * Energy efficient heat transfer | * Automatic tenant billing |

Table 5 NTT Technologies Supporting Building Intelligence

| Environmental Planning | |
|---|---|
| * Flexible Planning systems | - Zoning-related planning procedures, flexible office layouts, lighting, HVAC planning |
| * Office Furniture systems | - Office furniture layout procedures, workstation layout procedures |
| * Ergonomic planning systems | - Color strategies, increase of greenery, OA lighting & control, noise strategies |
| * Amenity planning, systems planning | - Hall and lounge, atrium and airshaft void, restaurant, lounge, rest area |
| * Maintainability planning systems | - Building systems, preventive maintenance strategies; failure diagnosis procedures |
| * Life-cycle planning systems | - Life cycle cost computation procedures, cost-efficiency cost-efficiency evaluation procedures |
| * Public communication space systems | - Rental intelligent offices; intelligent building information and showroom services |

**Table 5 NTT Technologies Supporting Building Intelligence**

| **Intelligent Building Construction System** | |
|---|---|
| * LAN configuring | - Cable shaft, PBX site and node accommodation space planning |
| * Floor wiring | - Under carpet cable and cellular floor duct techniques; double layered OA flooring |
| * Wall wiring | - Panel and cable-pole wiring |
| * Ceiling wiring | - Ceiling and cable-rack wiring; optical star links |
| * Flexible air conditioning (AC) | - Task oriented, distributed, VAV, condensationless air conditioning |
| * Flexible lighting circuit switching | |
| * Document conveying | - Document transfer robots, vertical conveyors - linear motors, compressed air |
| * Aseismic design | - Free access aseismic design - floor strengthening, piping, equipment installation |
| * Prevention of Electromagnetic Interference | |

### 8.4.1 NTT R&D

NTT R&D was established two and one half years ago. Members include such companies as United Technologies, Panasonic, Mori Construction, a Honeywell subsidiary, Carrier Corporation, and major banks. Several furniture manufacturers also are members.

NTT R&D promotes better total office environments, covering all areas of intelligent buildings. It also specializes in and teaches facility management courses. Another activity is performing office planning research.

### 8.4.2 NTT Building Technology Institute (NTT-BTI)

The NTT-BTI performs a wide variety of building related activities (32):

1. Building diagnosis and evaluation

2. Tests and inspections of building materials and systems

3. Consulting related to integrated development of regions and buildings

4. Planning, development, and utilization of building related computer systems

5. Publication of references and managing building documentation

The NTT-BTI stresses the importance of integration in the development of intelligent buildings. It notes that while the availability of hardware such as PBX's, LANs, computers, building and office automation systems and CAD in intelligent buildings are important, more vital is the software that controls the use and integration of these systems.

### 8.4.3 The Building Research Institute

The Building Research Institute (BRI) is a national building research laboratory, under the Ministry of Construction. It is the only national research organization focused on housing, planning and the building sciences. Unlike the other research organizations located in Tokyo, BRI is in Tsukuba Science City. It has a staff of 118 researchers and 54 support personnel (33).

It lists five major goals for its program:

1. The prevention of disasters; protecting cities and buildings.

2. The improvement of the living environment; urban planning and building environments, emphasizing physiological and psychological factors.

3. The rational organization of building production and the development of new building techniques.

4. The effective use of energy and resources.

5. The promotion of international cooperation.

# 9. Shared concerns - United States and Japan

## 9.1. Facility Management

### 9.1.1 Background

The design of intelligent buildings is merely the first step in the process of effectively integrating technology into an office work environment. The success of such buildings ultimately depends on how effectively they fulfill their intended purposes. The relatively new discipline of facility management is concerned with the operation of the building and its systems after construction.

The Japanese were exposed to the concept of facility management about ten years ago by having designers and others attend courses in the United States, visit buildings and interior design firms and participate in international conferences. These actions enabled them to take advantage of the experiences gained by their counterparts overseas, thereby avoiding many problems and perhaps speeding up the learning process by as much as 3-5 years.

The Japanese have been actively engaged in facility management for the past five years and are now integrating it more closely into their building design and management activities. For example, leading construction management firms specializing in intelligent buildings such as Taisei, Takenaka and Shimizu provide a complete range of services. They work with the client in planning, programming, negotiating for financing and developing a design team. They then conduct discussions with different client groups periodically. Sometimes they even manage the facility after completion. To assess building and job performance facility management sometimes includes a post occupancy evaluation (POE) using questionnaire surveys. The goal is to identify technologies and environmental attributes such as lighting, acoustics and air quality, to determine whether they impede or help office workers.

In the United States, the concept of facility management was initiated and fostered in the 1960's and 1970's by the Herman Miller Corporation, a furniture manufacturer. Its' intent was to ensure that the furniture designed was closely integrated into the office environment, thereby creating an attractive and effective work environment. A major concern was to suit furnishings to particular activities, while simultaneously facilitating necessary changes. Their solution was to develop a range of modular furniture components which can be configured according to specific requirements, e.g. panels, shelves, work surfaces, drawers, covers, and counter tops (34).

### 9.1.2 Importance of facility management - Japanese views

Facility management is becoming more important in Japan as computers are used more in building design and operations. Also, as automation and energy management becomes prevalent, it is gaining acceptance.

With CAD systems, more data can be rapidly collected and used to manage facilities. Computer aided facility management is being explored at present - a combination of CAD and data base systems. NOPA believes that facility

management is important but is largely overlooked in Japan; only 7 percent of their members have a facility management staff.

### 9.2 Building design and productivity

A major issue for many organizations has been to determine how intelligent buildings, and their advanced technologies, affect office worker productivity, which has been stagnant in the United States and Japan for many years. The primary stumbling block has been an inability to measure office worker productivity. IBM Japan uses a questionnaire survey twice a year to measure satisfaction which is thought to relate to productivity. IBI is also performing research to attack this problem.

The Japanese depend on several approaches to increase office productivity:
- More technology
- More amenity
- More responsiveness to individual needs
- Better integration of design with facility management
- Closer working relationship with end-user in defining needs and operating and managing the building after construction.

In the United States, productivity measurements generally have been limited to questionnaire surveys asking workers to assess productivity changes resulting from automated systems (or asking supervisors to make such evaluations of their staffs). In general, neither country has made much progress in developing measurements that are reliable or have proven validity. The problem remains.

## 10 Philosophies of Intelligent Buildings - United States and Japan

### 10.1 United States - National Academy of Sciences (NAS)

An assessment of intelligent buildings should not be limited to structural and technological issues. As stated in a study by the NAS (6):

"The shift in office population, from clerical to knowledge workers, has intensified the demand for a high quality work environment, relief from intensive video display terminal based work, and a "voice" in shaping and controlling the work setting. The underlying assumption made by knowledge workers, and increasingly supported by organization, design, information, and ergonomic professionals, is that increased organizational productivity is dependent on the "unleashing" of knowledge workers; i.e. providing them the tools and opportunities to use their skills, knowledge and decision-making abilities. This is the major challenge in designing the technologically advanced office building."

### 10.2 Japan

#### 10.2.1 Takenaka Komuten Corporation (7)

"Offices need substantial office automation and communication equipment to efficiently conduct business, use data from external sources, and processing large volumes of information. At the same time people want working conditions that provide not only a pleasant and intellectual atmosphere, but also allow them to preserve individuality and creativity. Such offices must be furnished with the necessary hardware to support the human intelligence that deals with this information-oriented society. Yet, the offices must provide a warm and comfortable environment that focuses on the needs of human occupants."

#### 10.2.2 Taisei Corporation - Human Creative Office (35)

"It is time for us to find an alternative to the hardware-intensive intelligent buildings. No matter how modernization may advance, it is humans who have to use an office. And it is also humans who do creative work. An office should be comfortable, should represent the corporate culture and have its own identity, should enable us to use its function effectively and be human oriented. The office must have the flexibility and functionality to keep up with changes in society and the organization.

The office is the embodiment of corporate culture. The building should have an identity in its outlook. Every floor and each section should have individuality. The employees personality should be respected. The ground level of a building should be open to the public and serve as ‘an oasis in the city’. A ‘green network’ around the building should beautify the surrounding area. Communication spaces are provided for business conversations, meetings and informal conversations. By using art works and other decorations, the company image is improved and workers have a ‘refreshment’ area."

### 10.2.3 Nikken Sekkei (36)

"The goal of intelligent buildings is to realize the integration of amenity, safety, security, productivity and economy. Optimum control of a variety of conditions is now possible thanks to progress in microcomputers. Temperature systems can be changed according to the season and the time of day. Fragrances can be introduced as desired. Work is progressing to control illumination and masking noise from the workstation, enabling individuals to tailor environments to particular needs and desires, rather than accepting conditions considered desirable by 'the majority of people'."

### 10.2.4 Shimizu Corporation (37)

"There is a growing demand within our society today for the reconsideration and improvement of every aspect of the environment we live, work and play in. Such simplistic attitudes that put technology and expense ahead of everything else in the field of construction will no longer be tolerated. Modern buildings should not be considered in terms of functional performance alone.... We are striving to create what we call a "harmonious living environment", the basis for a futuristic society that will have both a human and functional emphasis. This environment encompasses many components, cultural, economic and industrial; ideally, it should consist of pleasant living and working spaces integrated with a solid basis of social services."

### 10.2.5 Matsushita/CRSS "Officing" (38)

In 1987, a roundtable meeting of Japanese and United States participants exchanged views about intelligent buildings. The resultant publication, "Officing", presented views similar to those expressed by the organizations above. For example:

"A convenient environment is not enough for human office workers to work efficiently. A comfortable environment is of equal importance. A building should not only be an intelligent place, it should be an intimate place. An intelligent building should offer not only high-tech services, but high-touch services; training to effectively use the technologies. This is especially true for smaller firms, not equipped to establish full-time training activities."

At the workshop, Mr. Nambu formulated a strategic view of intelligent building design in Japan, as follows:

"We view the Japanese economy according to three stages of promotion. The past stage is the period of production promotion. The present stage is the period of marketing promotion. And, the future stage is the period of prearrangement promotion.

In the past, the company could increase profits by producing products, only taking into consideration the producing capacity. At present, profits are made by developing and producing products satisfying user needs. In the future, however, the company which can prearrange and propose the conditions customers desire will survive and grow."

Mr. Natsuno, a representative at the roundtable from Matsushita Electric Works, Ltd, summarized the discussion:

"The definition of intelligent buildings will expand to include not only office buildings but residences, stores, hotels and whole cities. An intelligent city requires the development of a comfortable environment for human beings containing functions based on advanced information technology integrated with functions for recreation, relaxation and living.

Comfortable environmental development is crucial to people. In Japan, funding of planning and design for construction, electricity and air conditioning are adequately carried out during planning and basic design. However, interior design, layout and furniture, which are most important for people, are overlooked in most cases.

Facility management, including interior design, layout and furniture, should be conceptually defined in the planning stage so that they receive adequate funding. This is the most important point in promoting any project for intelligent buildings. The future of intelligent buildings depends entirely on how such facility management can be improved."

**10.2.6 NTT Building Technology Institute (BTI) (39)**

"The intelligent building should be a comfortable and humane setting. Office layout, ergonomics, furniture and facilities such as atria, fitness centers, cafeterias and places to relax are important components for an effective working environment."

**10.2.7 Mori Building Co., Limited (23)**

"Ark Hills represents the birth of the 'intelligent city', a concept that extends beyond the intelligent building... we believe this space concept represents a major step forward toward the goal of reintegrating human activities split up as the result of industrialization, and of creating coordinated urban spaces that can meet a variety of human needs.

Ark Hills has, within its grounds, a television station, an office building, a hotel, a concert hall, plaza, and other facilities. By networking these facilities, I would like to develop an educational environment in the widest sense of the word. I hope that Ark Hills will become the cradle of 21st century civilization" (Taikichiro Mori, Chairman, Mori Building Co).

## 11. Conclusions

Viewed strictly from a technological perspective the Japanese approach to intelligent buildings bears many resemblances to the United States experiences. Japanese firms are incorporating new technologies, information, communications, and building systems to enhance organizational productivity. They are working to overcome many of the same problems as their counterparts in the United States, such as the lack of compatibility and standardization of hardware and software systems produced by different manufacturers.

In contrast to United States intelligent buildings, Japanese offices more often:

* Rapidly employ the latest technologies, e.g.
  - Innovative HVAC systems, highly integrated electrical lighting and daylighting systems.
  - Daylight and sunlight delivery systems to building interiors
  - Advanced building movement monitoring and control systems.
  - Widespread use of smart cards for multiple purposes
* Employ shared workstations
* Emphasize amenity and consideration of the office as a home away from home.

While technological factors usually come to the forefront in discussions about intelligent buildings, perhaps the most important issues identified by United States and Japanese designers, engineers, users, and researchers concern not technological, but "process" and "quality of life" issues. For example, the NAS study (7) cited earlier indicates that:

"The shift in office population, from clerical to knowledge workers, has intensified the demand for a high quality work environment, relief from intensive display terminal based work, and a "voice" in shaping and controlling the work setting. The underlying assumption made by organization, design, information, and ergonomic professionals, is that increased organizational productivity depends on "unleashing" knowledge workers; i.e. providing the tools and opportunities to use their skills, knowledge, and decision-making abilities. This is the major challenge in designing intelligent office buildings...

In order to increase the likelihood that the technologically advanced office will achieve its potential, appropriate performance criteria should be formulated, and then a process established to ensure that the criteria are not compromised during design and construction."

While these issues have been identified in the NAS study and elsewhere, intelligent building design in the United States has been a continuation of traditional practices for the most part. As a result, many building users have encountered unanticipated problems. Among these unwanted surprises are:

1. Building management, communication and office automation systems often do not perform as expected.

2. Difficulties are encountered in integrating hardware and

software systems produced by different manufacturers.

3. Environmental problems such as noise, glare, "stuffy air", and difficulties in maintaining proper temperature control are common.

4. Furnishings are unsuitable for new office technology systems.

5. There is insufficient flexibility of various building and office systems as well as workstations - subject to frequent upgrades and changes.

6. First cost considerations predominate over long term potential benefits; changes are costly and often result in degraded environmental and job performance.

7. Building amenities are often termed "frills" that are eliminated when cost cutting decisions are made. Offices are often judged by their employees to be sterile and lacking in "warmth" and "humanity".

8. The anticipated gains in productivity are often not achieved.

Many of these problems are attributable to the piecemeal approach typical of building practices in the United States. Again, from the NAS report:

"Traditionally, the construction of a building and the outfitting of its interior have been treated as separate and distinct activities... the architect oversees the structure and oversees the construction, after which an interior design firm plans and oversees the outfitting of the interior space... The responsibility for incorporating electronic technology is left to equipment vendors and building occupants, who often make ad hoc building modifications to accommodate electronic equipment and cables"

Finally, the NAS concludes that:

"A technologically enhanced building provides an ever changing complex system in support of an organizational mission. It is composed of a variety of systems and subsystems which serve building users, building operators, and building owners/managers. The effectiveness of these systems is dependent upon their responsiveness to the people who use and manage the building."

While the NAS report advocates a systems orientation for United States designers and builders, the Japanese building industry and several major user organizations, are already practicing this approach. Moreover, their perspective is broad and far reaching. This long term view is reflected both from an organizational standpoint and as a society, evidenced by a commitment of resources and technical aid from governmental institutions.

The concept of the intelligent building is a key to this strategy. It is being approached as a system to be marketed as a unit with closely integrated building management, office automation, telecommunications, and other systems. (While their current practices are moving in this direction, existing and planned buildings fall short of this goal.) Moreover, the Japanese have taken

an all-encompassing view of the needs for building intelligence, including the workstation, office, building, building complexes, cities and worldwide organizational operations.

This systems approach is evident in the work of the largest construction management and architectural/engineering firms and supported by in-house state-of-the-art building research laboratories. Unlike the United States however, two major government ministries [The Ministry of Construction (MOC) and the Ministry of International Trade and Industry (MITI)] are actively promoting this concept and supporting activities to enhance its development. These ministries provide support to foster office design to take full advantage of new technologies in enhancing office productivity while improving working conditions for office workers. The financial community also provide incentives for developers of intelligent buildings.

Perhaps the feature which most distinguishes intelligent buildings from traditional ones is the degree of interdependency among the various systems housed in buildings and between building users and these systems.

For example, between (among):

* Communication and office technologies
* Workstations with one another; with central processors
* Wiring - power, data, voice; - furniture
* Design and facility management functions
* Environmental needs of users and those of equipment
* Needs of users and designers
* Workstation features
* Working groups
* Office - building - complex - city - world
* Building exteriors and interiors
* Work and leisure
* People and technologies

Effectively integrating these many diverse systems - technical and human based - has been a high priority objective for the Japanese building community, user organizations and governmental agencies. They are expending considerable resources to design intelligent buildings to improve job performance and enhance organizational effectiveness, while providing desired amenities for their workers. Their long term perspective is likely to result in systematic progress toward achieving these goals.

Bibliography

1. NOPA study paper, NOPA, Tokyo, Japan (Undated).
2. Rubin, A. "The Automated Office: An Environment for Productive Work, or an Information Factory", NBSIR 83-2784-1, Aug 1983.
3. Rubin, A. "The Automated Office: An Environment for Productive Work, or an Information Factory - Executive Summary" NBSIR 83-2784-2, Dec 1983.
4. Rubin, A. "A Revised Interim Guideline for Automated Offices" NBSIR 86-3430, Aug 1986.
5. Rubin, A. "Office Design Measurements for Productivity - A Research Overview" NBSIR 87-3688, Dec 1987.
6. Rubin, A. and Gillette, G. "Interim Guideline for Workstation Design" NISTIR 89-4163, Aug 1989.
7. "Electronically Enhanced Office Buildings", NAS, National Academy Press, Washington, D.C. 1988.
8. Rubin, A. "High Technology Office Evaluation Survey - A Pilot Study", NISTIR 4354, June 1990.
9. "Offices Today - Searching for a Richer and Better Environment", Takenaka Komuten Corp, Osaka, Japan.
10. Engineering News Record, 5 July 1990
11. Takenashi, M. "Intelligent Buildings in Japan", ASHRAE Forum on Advances in HVAC Systems in Japan, Atlanta, GA, Feb 1990.
12. "Joint Report of the U.S. - Japan Working Group on the Structural Impediments Initiative", June 1990.
13. Conversation with R. Geissler, Intelligent Building Institute (March 1990).
14. North American Office Market Review - 8, BOMA, 1989.
15. "Offices Today - Searching for a Richer and Better Environment", Takenaka Komuten Corp, Osaka, Japan (Undated).
16. Nikken Sekkei Brochure, Nikken Sekkei, Tokyo, Japan (Undated).
17. "Tasei Today" Tasei Corporation Brochure, Tasei Corp, Tokyo, Japan (Undated).
18. Toshiba Company Brochure, Tokyo, Japan (Undated).
19. "New Patent Office Building - To the Era of Paperless Office Work", Ministry of Construction, Tokyo, Japan, June 1989.
20. "Crystal Tower", Takenaka Corp, Tokyo, Japan (Undated).
21. "Fujitsu Kansai Systems Laboratory", Fujitsu Corp., Tokyo, Japan (Undated).
22. "IBM Japan - Hakozaki Office", Nikken Sekkei Corp, Tokyo, Japan (Undated).
23. "The Total Environment City - Ark Hills", Mori Construction, Tokyo, Japan (Undated).
24. "Makuhari Techno Gardens", Shimizu Corp Brochure, Tokyo, Japan (Undated).
25. "Sunlight Collection and Transmission System - Himawari", La Foret Engineering and Information Service, Tokyo, Japan (Undated).
26. "Sol Air Heat Pump", Takenaka Brochure, Takenaka Komuten Corp, Osaka, Japan (Undated).
27. "Vapor Crystal System", Takenaka Komuten Corporation, Osaka, Japan (Undated).

28. "Ice Chilled Water Mixture Transportation System for District Heating and Cooling", Ohbayashi Corp., Tokyo, Japan (Undated).
29. "Automatic Construction System, Ohbayashi Corp., Tokyo, Japan (Undated).
30. Takaneshi, M. "Intelligent Buildings in Japan", ASHRAE Forum on Advances in HVAC Systems in Japan, Atlanta, GA, Feb 1990.
31. New Office, Inaugural Issue, NOPA, Tokyo, Japan, Sep 1987.
32. NTT Building Technology Institute Description, NTT Bldg Tech Inst, Tokyo, Japan (Undated).
33. Building Research Institute Brochure, Tsukuba City, Japan, 1990.
34. Probst, R. "The Office - A Facility Based on Change" Herman Miller Res. Corp, Ann Arbor, Mi, 1968.
35. "Human Creative Office", Tasei Corp, Tokyo, Japan (Undated).
36. Orihara, A. "Amenity, Safety, and Security in 37. Intelligent Buildings", Nikken Sekkei, Tokyo, Japan (Undated).
37. Shimizu Corporation Brochure, Tokyo, Japan (Undated).
38. Sutherland, D. ed "Officing - An International Round table on Intelligent Buildings" - CRSS/Matsushita Electric Works Research Publication, Jan 1988
39. "Intelligent Revolution - Giving Form to Intelligence", NTT Intel Planning & Dev, Tokyo, Japan (Undated).
40. "Study on the Office Environment", NOPA, June 1988.
41. "Needed Office Improvements", MITI Business Behavior Division, Industrial Policy Bureau, Sep 1987.

**Appendix 1 NOPA Studies**

The New Office Promotion Association (NOPA) conducted a number of surveys dealing with the office environment. The findings and general conclusions are summarized below.

The typical Japanese office is very uniform with regard to hardware, layout and arrangements of desks. Most offices consist of a large room with desks arranged face-to-face (75-80%). Few offices have louvered lighting, VAV air conditioning systems, carpeting or plants, etc.

One study compared Japanese offices with those in the United States and West Germany (40). "Study of the Office Environment - Summary", June 1988, NOPA.

A major issue examined was space usage. First they compared the space allocated to each person in offices in the United States, Germany, and Japan. As noted in the following table, the U.S worker more than twice the space of the Japanese worker, with the German employee being midway between the other two groups. In an effort to determine whether the same stringent office space limitations were applied to foreign enterprises located in Japan, organizations located in Tokyo and Osaka were studied. From the table below it is evident that foreign organizations did not conform to the space limitations imposed by domestic firms.

**Table 6 Comparison of space usage: United States, W. Germany and Japan – Actual space per person (square meters)**

| | | | |
|---|---|---|---|
| | U.S. | W. Germany | Average |
| Foreign Enterprise | 22.2 | 14.8 | 20.6 |
| Japanese Enterprise | Tokyo | Osaka | Average |
| | 8.8 | 7.5 | 8.6 |
| Foreign Enterprise | Tokyo | Osaka | Average |
| in Japan | 14.3 | 17.4 | 15.0 |

Other major differences were apparent when Japanese offices were compared with those in West Germany and the United States In Japan, 40.5 percent of the office spaces are open, with no partitions between the desks. Furthermore, only 1.2 percent of the offices have office landscaping, e.g. plants, non-uniform layout. In the United States and West Germany, 39 percent of offices have office landscaping. In Japan, offices are designed with desks facing one another in 92.6 percent of the spaces. In West Germany and the United States, this layout is virtually non-existent.

The Japanese offices generally not only offer less space to occupants, but other 'amenities' also are lacking in many instances. For example, with respect to furnishings, Japanese offices use vinyl in 93.3 percent of their chairs as compared to the preponderant use of cloth covering

in West Germany and the United States. As for floor carpets, in Japan 79.7 percent of the floors have no covering, while in the United States and West Germany, 85.7 percent of the floors are carpeted. Finally, few Japanese office buildings have refreshment areas; 11.3 percent, compared with 66.7 percent in the United States and West Germany.

Managers and workers believe there is a large gap between Japanese and foreign offices. Firms operating under the same conditions and restraints as Japanese companies have better office working conditions. Foreign firm members operating in Japan expressed the opinion that Japanese office environments are "poor" (81%). Managers of Japanese companies (55%) believe that Japanese offices are inferior to foreign ones.

In another investigation, the importance of the office environment was evaluated by 251 top executives. Table 7 summarizes these findings. Reasons for the importance of the environment are given by the percentage of respondents agreeing to each characteristic.

**Table 7 Reasons given for importance of office environment.**

| | |
|---|---|
| Morale | 80% |
| Creativity | 69% |
| Productivity | 67% |
| Corporate Image | 67% |
| Recruiting good people | 61% |

NOPA also examined the reasons for dissatisfaction among office workers. Table 8 summarizes these findings. About 79 percent of respondents felt that the bad office impeded their work.

**Table 8 Dissatisfaction ratings of Japanese office workers.**

| | |
|---|---|
| No refreshment areas | 74% |
| Small space | 49% |
| Excessive documents | 49% |
| Uncomfortable HVAC | 43% |
| Lack of character | 42% |
| Confusing layout | 36% |
| Exposed wiring | 36% |
| Old furniture | 34% |
| Lack of privacy | 31% |
| Noisy | 28% |

The Business Behavior Division of MITI conducted a study of the needed improvements for Japanese offices. Table 9 summarizes these findings.

| Table 9 Needed office improvements | |
|---|---|
| 1. More space per person | 35.8% |
| 2. Efficient and rational filing system | 30.9% |
| 3. Appropriate air conditioning | 28.4% |
| 4. Appropriate layout | 24.7% |
| 5. Appropriate location of OA equipment | 19.8% |
| 6. Space for a change | 13.6% |
| 7. Change of color | 11.1% |

NOPA indicates that managers and workers have a limited understanding of the need for improved office environments. It is necessary to educate them about the benefits of improved work settings. An indication of the low priority given of offices in Japan, only 13 percent of Japanese companies use experts in designing offices as compared with 77 percent in the United States. Similarly, 77 percent of the buildings in the United States are said to have facility managers, while only 13 percent of the Japanese buildings have them.

**Appendix 2.**

**Organizations contacted:**

Building Research Institute
Ministry of Construction
Tatehara 1,
Tsukuba Science City, Ibaraki 305, Japan

Delphi Research Inc.
8-13 Yonban-cho
Chiyoda-ku, Tokyo 102, Japan

Fujitsu Kansai Systems Laboratory
Shiromi 2-2-6
Chuo-ku, Osaka 540, Japan

GK Industrial Design Associates
2-19-16 Shimo-ochiai, Shinjuku-ku
Tokyo 161, Japan

Itoki Co., Ltd
7-3, Ginza 3-Chome
Chuo-ku, Tokyo 104, Japan

Japan Facility Management Association
Suzutaka Building
3-6-8 Yushima
Bunky-ku, Tokyo 113, Japan

Japanese Association of Refrigeration
San-ei Building
8.San-ei-cho, Shinjuku-ku, Tokyo, Japan

Kokushikan University, Architecture Division
4-28-1 Setagaya, Setagaya-ku
Tokyo 154, Japan

La Foret Eng & Info Svc Co, Ltd
Himawari Building, Toranomon 2-7-8
Minato-ku, Tokyo 105, Japan

Mitsubishi Estate Co, Ltd.
4-1, Marunouchi 2-chome
Chiyoda-ku, Tokyo, Japan

Mori Building Management Co. Ltd
Ark Mori Bldg
12-32 Akasaka 1-chome
Minato-ku, Tokyo 107, Japan

New Office Promotion Association
Noyori Building 2-17
Shibadaimon 1-chome
Minato-ku, Tokyo 105, Japan

Nikken Sekkei Ltd
1-4-27 Koraku, Bunkyo-ku
Tokyo 112, Japan

Nikken Sekkei Ltd
6-2 Koraibashi 4-chome
Chuo-ku, Osaka 541, Japan

NTT Intelligent Planning and Development Corporation
Toranomon Ohtori Bldg, 5th Floor
1-4-3 Toranomon
Minato-ku, Tokyo 105, Japan

NTT Building Technology Institute
9-11 Midori-cho 3-chome
NTT Musashino R&D Center
Musashino-shi, Tokyo 180, Japan

Office Facilities Institute
108 Shiba 4-9-3
Shiba, Ishi Building
Minato-ku, Tokyo, Japan

Ohnishi Netsugaku Co. Ltd
1-1, Kanda Ogawa-Machi
Chiyoda-ku, Tokyo 101, Japan

Osaka University, Dept of Architectural Engineering
2-1, Yamadaoka, Suita
Osaka 565, Japan

Patent Office
3-4-3 Kasumigaseki, Chiyoda-ku
Tokyo 100, Japan

Shimizu Corporation
No. 16-1, Kyobashi 2-chome
Chuo-ku, Tokyo 104, Japan

Makuhari Techno Project
Shimizu Corporation
Design Studio
No. 3 Nakase 1-chome
Chiba-shi. Chiba 280, Japan

Takenaka Corporation
Business Promotion Dept
1-13 4-chome, Hom-machi
Chuo-ku, Osaka, Japan

Takenaka Corporation
Facility Management Group
13-1 1-chome, Kachidoki
Chuo-ku, Tokyo, Japan

Taisei Corporation
344-1 Nase-cho
Totsuka-ku, Yokohama City 245, Japan

Toshiba Corporation Principal Office
Concept Engineering Division
1-1 Shibaura 1-chome
Minato-ku, Tokyo 105-01, Japan

Toyo Carrier Engineering Co. Ltd.
Mitsui Bldg. Annex No.2
4-4-20, Nihonbashi-Hongoku-cho
Chuo-ku, Tokyo 103, Japan

University of Electro-Communication
1-5-1 Chofugaoka, Chofu-shi
Tokyo 182. Japan

University of Tokyo. Department of Architecture
Hongo, Bunkyo-ku
Tokyo 113, Japan

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In May 1990, the author of this report visited Japan at the request of the Department of Commerce, to assess the Japanese experiences with 'intelligent building' design, construction and use. The state-of-the-art was determined by visiting advanced buildings, building complexes, and interviewing architects, engineers, and researchers and academics. Discussions also were conducted with organizations engaged in promoting the use and design of intelligent buildings.

In general, the Japanese experiences have paralleled those in the United States. In both countries, advanced building technologies have been employed to advance organizational effectiveness and personal productivity. A major problem shared by the two countries has been the lack of standardization of hardware and software (protocols), resulting in major difficulties in integrating equipment from different manufacturers, and in some instances, diverse products from the same manufacturer. Intelligent building design in Japan differs from that in the United States in several ways. They incorporate new systems and products into their buildings as soon as they become available. They stress the need for a high quality environment - amenity - more than we do. The commitment for developing improved intelligent buildings includes active governmental involvement by two major ministries and other institutions such as banks.

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